Research in Veterinary Science 149 (2022) 36–46

Contents lists available at ScienceDirect

Research in Veterinary Science

journal homepage: www.elsevier.com/locate/rvsc

Owner perception of health of North American dogs fed meat- or plant-based diets

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ARTICLE INFO

Keywords:
Alternative pet diet
Canine nutrition
Health perception
Pet owner survey
Unconventional diet
Vegan dog
Vegetarian dog

ABSTRACT

Background: Some dog owners elect to feed their dog a plant-based food either as part of or for their entire dietary intake. Being omnivores or facultative carnivores, a strictly plant-based diet is not the natural type of food dogs evolved to consume, leaving some question as to whether this feeding management strategy is safe and healthy for dogs.
Objectives: This study surveyed owner perceptions of health and wellbeing of dogs and compared between those fed meat-based and plant-based diets.
Methods: A web-based questionnaire was distributed to pet owners to collect data on dog characteristics, husbandry, health and wellbeing. Univariate comparisons between diet groups was made by chi square analyses or Kaplan-Meier tests as appropriate, with a significance cut-off value of 0.05. Multivariate models were negative binomial and logistic regression for count and categorical data, respectively.
Results: Owners feeding plant-based diets to their dog reported fewer health disorders, specifically with respect to ocular or gastrointestinal and hepatic disorders. Dog longevity was reported to be greater for dogs fed plant-based diets. Owners feeding plant-based diets to their dogs relied less on veterinary associates for nutrition information, versus dog owners feeding meat-based diets.
Conclusions: Dog owners feeding a plant-based diet did not perceive adverse health effects in their dogs. The results might suggest an association between feeding a plant-based diet and perceived health and longevity, however inherent bias and limitations associated with surveys of owner perception must be considered, and objective research is required to determine if plant-based diets truly affect canine health.

1. Introduction

The domestic dog (*Canis lupus familiaris)* belongs to the order Carnivora, though this taxonomic nomenclature may come across as misleading. As one may expect from the name, order Carnivora contains obligate carnivores, such as Felidae, but it also includes the herbivorous Ailuropodidae (pandas) and the omnivorous canids (Wozencraft, 2005). Though it is commonly thought that the diets of dogs, and their ancestors the wolves, must be comprised of the tissues of other animals, their natural diets can vary greatly, with some being composed predominantly from plant matter (Zlatanova et al., 2014). Most conventional dog foods (commercial kibble and wet products) are typically composed of animal-derived ingredients from the agriculture system producing products for human consumption and thus contain large quantities of commonly farmed animals, namely chicken, cattle, swine, sheep, duck, turkey, deer and a number of fish species. At this time, diets containing 'novel' proteins are also popular, including ingredients from more exotic animals such as bison, rabbit, kangaroo, and alligator. Comparatively, few dog foods are devoid of animal ingredients, likely resulting from a combination of the traditional cooperation of the human and pet food production systems, as well as the general acceptance of the dog as being a facultative carnivore who thrives on a meat-based (MB) diet.

Though there is some disagreement among both pet keepers and pet health professionals, it is generally accepted that dogs can thrive when fed nutritionally complete and balanced diets devoid of animal ingredients (FEDIAF, 2017). Meat-free therapeutic diets have been designed to treat and manage certain health conditions, with indications for dietary hypersensitivity, gastroenteritis, inflammatory bowel disease, lymphangiectasia, protein-losing enteropathy, pancreatitis, exocrine pancreatic insufficiency, malabsorption, hepatic

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https://doi.org/10.1016/j.rvsc.2022.06.002
Received 4 March 2021; Received in revised form 21 December 2021; Accepted 6 June 2022
Available online 11 June 2022

encephalopathy, urate urolithiasis, cystine urolithiasis, hyperlipidemia and liver disease reported by the manufacturers (Purina® Pro Plan Veterinary Diets® HA Hydrolyzed® Canine Formula; Rayne Nutrition™ Plant-Based™; Royal Canin® Veterinary Exclusive Vegetarian Canine). However, it is recognized that formulation and production of complete and balanced diets for dogs is more challenging when limited exclusively to non-animal ingredients (FEDIAF, 2017; Dodd et al., 2018; Kanakubo et al., 2015). In particular, plants are typically limited in sulfur amino acids and the omega-3 fatty acids eicosapentaenoic acid and docosahexaenoic acid. Additionally, plants themselves do not contain all essential vitamins, though they may contain precursors or related compounds(Dodd et al., 2018). For example, plants do not contain pre-formed retinol (vitamin A), though some contain carotenoids from which it may be derived (Deming and Erdman Jr, 1999), and the dietary requirement of vitamin D is defined in terms of cholecalciferol (vitamin D3), yet the form of vitamin D typically found in non-animal ingredients is ergocalciferol (vitamin D2) (NRC, 2006; Hazewinkel and Tryfonidou, 2002; How et al., 1994), while cobalamin (vitamin B12) is also lacking in terrestrial plants, though produced by microbes, including yeasts and microalgae (NRC, 2006). Plant provision of minerals, particularly calcium, can also be low in comparison to the dietary requirements of dogs, though non-animal inorganic sources are common and widely used throughout the petfood industry.

Few previous publications have examined the impact of feeding a plant-based (PB) diet on the health of domestic dogs. While nutrient deficiencies have been documented in PB dog foods (Semp, 2014; Zafalon et al., 2020), no adverse health outcomes attributable to diet have been reported. Indeed, even in dogs with exceptional exercise demands, a vegetarian diet was demonstrated to maintain the limited parameters measured within normal limits (Brown et al., 2009). No case studies have been published either demonstrating efficacy of plant-based diets in maintenance of canine health, nor identifying negative health outcomes associated with feeding a plant-based diet to dogs. Nevertheless, being such a novel feeding trend practiced by approximately 2% (Dodd et al., 2019a) of dog owners (around 1 million dog owners in the USA alone) (AVMA, 2018) the incidence of reporting such dietary-associated conditions may be under-represented. To date, owner perspectives on health of dogs fed plant-based, a topic which may reveal areas in which further research regarding health effects of plant-based diets is indicated, have not been investigated. The objective of this study was thus to survey a sample of dog owners and compare owner perception of health and wellbeing of dogs fed PB and MB diets.

2. Methods

This study was approved by the University of Guelph Research Ethics Board (REB # 18–07-039).

2.1. Survey design

An online virtual questionnaire was designed and distributed using the Qualtrics (Qualtrics XM, Provo, Utah, USA) online platform. Questions were based on previously validated survey items (Schneider et al., 2010; Lavan, 2013) and were piloted by the authors and pet owners before the survey was made available to potential participants. Inclusion criteria were owners of cats or dogs living in the United States of America or Canada. (Data relating to cats are presented elsewhere (Dodd et al., 2021).) Exclusion criteria included age younger than 18 years, non-ownership of a dog, and living outside of the USA or Canada. Incentive to participate was provided as a random draw to obtain a gift certificate for a pet store of the respondent's choosing. Eight prizes of $25CAD gift cards were available, and participants could choose to enter the prize draw by entering their email address at the end of the questionnaire. Identifying data were removed from the main data and stored separately until the end of the data collection period, such that participant responses were not identifiable. After the prize draw was conducted and the winning participants were contacted, all participant emails were deleted.

The questionnaire included 36 multiple-choice and Likert scale, 8 short answer, 7 sliding scale (0−100) and 1 ranking questions. The questionnaire used flow logic to reveal species-specific questions, depending on the type of pet the participant was answering for. Owners of both cats and dogs were presented both sets of questions. Participants could choose not to answer or skip questions, as per the requirements of the Research Ethics Board. Questions were designed to collect demographic information about pet owners, pet species, breed, sex, age, acquisition, lifestyle (indoor/outdoor), as well as wellness indicators based on previously validated survey items (Schneider et al., 2010; Lavan, 2013). Body condition score (BCS) was selected by the respondents based on images from the World Small Animal Veterinary Association body condition scoring chart (WSAVA, 2013), randomly ordered to avoid bias. For this 9-point method, scores from 1 to 3 are underweight, 4 to 5 are ideal, and 6 through 9 are overweight. Faecal condition score was selected by the respondent based on images corresponding to the Bristol stool chart (Anonymous, 2017), randomly ordered to avoid bias. By the Bristol stool chart, faecal scores of 1 to 2 are abnormally hard to constipated, 3 to 4 is normal, and 5 through 7 range from soft to diarrhoea. To determine prevalence of health disorders, body systems and common disorders were listed, along with an “other” category, and respondents were asked to select the appropriate system and describe their dog's specific disorder. These included: behavioural, cancer, cardiovascular (heart), dental, dermatologic (skin), diabetes, ear, endocrine, eye, gastrointestinal, hyperthyroid, kidney, liver, musculoskeletal, neurologic, obesity, parasites, reproductive, seizures, trauma/injury, urinary, other. The questionnaire is available as a supplementary file.

2.2. Survey distribution

A link to the survey was distributed via email and postcards to customers of Canadian and American pet food retailers, including deliberate distribution to clients of the largest PB pet food retailer in Ontario, Canada. This convenience sampling was utilized to increase the sample size of dogs fed PB, as it was expected only around 2% of dogs are fed plant-based exclusively (Dodd et al., 2019a) and a statistically significant sample size would be difficult to obtain using random sampling. As well, the survey was promoted in online dog-related groups on social media (Facebook, Inc., Menlo Park, California, USA). The questionnaire, which was available in English only, was made accessible for nine months, from June 2018 to March 2019. Respondents represented a convenience sample of pet owners voluntarily participating in the study.

2.3. Survey analyses

Survey responses were included for analysis for each question that was completed, incomplete or skipped questions were not included for analysis. Dog breeds were categorized into breed types based on phenotypic and genetic similarities (Turcsán et al., 2011; Voith et al., 2009). Description of dog diet was collected in an open-text question and, where sufficient information was obtained, categorized based on ingredients (MB, PB) and processing (commercial heat-processed, homemade, raw) or a combination of the aforementioned (ie: some dogs were fed more than one type of food on a regular basis). The term PB referred to a diet that contained no animal ingredients, while the term MB referred to any diet including animal-derived ingredients. Thus, while a MB diet could also include plant-based ingredients, a PB diet included no animal-derived ingredients. In addition to the main diet, information was also collected regarding the feeding of treats (commercial heat-processed, raw, homemade), table foods and supplements, and categorized based on ingredients (MB of PB). Dogs fed a PB diet but also given MB treats or snacks and/or supplements containing animal-derived products, were categorized as PB + MB. Dogs reported to

have free access outdoors and/or ability to hunt were not considered to have a strictly PB diet even if fed PB. These dogs were re-categorized as PB + MB/H, a group that included dogs fed a PB diet but either supplemented with a MB treat, snack or supplement and dogs fed only PB but with hunting ability. Dog wellness measured by Likert scale was reported directly (e.g.: poor, fair, adequate, good, very good), while sliding scale data were translated by the survey software into a value ranging from 0 to 100. Dog health disorders were offered in a multiple-choice question, with the option of 'other' for input by the respondent. Owner-reported 'other' health disorders were categorized by a veterinarian (SD) and included for analyses. Based on the responses, aural, behavioural, musculoskeletal, parasites, reproductive and trauma/injury were removed as categories and not included in statistical analysis. The majority of aural disorders were actually external ear infections, a dermatopathy, and thus considered in that category. True behavioural disorders were difficult to differentiate from issues of training or lifestyle (such as "he hates when anyone touches his paws", "unsociable", and "she doesn't listen very well"). Reported musculoskeletal and trauma/injury issues were difficult to interpret, with ambiguous descriptions and anecdotes of incidents that were believed to have occurred prior to current ownership, such as "she has scars of dog bites from when she lived on the streets before being rescued", "she had two broken legs when I rescued her, she limps a little. Not sure how her legs were broken", and "had shell casings from a type of pellet in her ear and shoulder". The parasite category was dropped as responses were typically regarding puppy worming or simply indicated that the dog was regularly treated with *endo-* or ectoparasite medications; reproductive disorders were similarly dropped as the most common reported issue was either having puppies or desexing surgery. The remaining variables were recategorized to: cardiac, dental, dermatologic, endocrine, gastrointestinal and hepatic, lower urinary tract, neoplasia, obesity, ophthalmic, and renal.

2.4. Statistical analyses

All statistical analyses were performed using Stata/IC 15.1 (StataCorp, College Station, Texas, USA) statistical software package. Descriptive statistics included frequency (n) and percentage (%) presented for most data (type of pets, location and time of dog acquisition, breed, indoor/outdoor management, diet and supplementation, motivators for selection of dog food, resources for information about canine nutrition). Frequency and percentage were also used for data collected using Likert scales for ranked data. Mean and standard deviation were presented for normally distributed data (dog age, duration of dog ownership, duration of feeding and lifespan of previous dogs [all measured in years]). Median and range was presented for ordinal data (BCS, FS) and count data (number of dogs kept, number of health disorders per dog).

Univariate comparisons between diet categories and responses related to pet food purchasing behaviours and pet nutrition information resources were conducted using χ^2 testing (see Tables 4 and 5). These analyses were performed when comparing between diet categories only (pet food purchasing, nutrition resources), without consideration of potential confounders. Age of previously owned dogs at death was compared among diet groups using Kaplan-Meier statistic.

Statistical models were selected based on the nature of the variable of interest – either count, binary or continuous data. The relationship between number of health disorders per dog, measured as count data, and diet type was modelled using multivariate negative binomial regression. Within the model, the dependent variable was the number of health disorders per dog. Independent variables considered included dog diet (3-level categorical: PB, PB + MB/H compared to MB), dog age (years), dog age squared (years squared), sex (2-level categorical: male compared to female), sex status (2 level categorical: intact compared to desexed), breed type (14-level categorical: collies and small herding dogs, large shepherds and livestock dogs, mastiffs and bulldogs, Nordic breeds, retrievers, scent hounds, sighthounds, spitz and primitive dog breeds, terriers, toys, working and hunting dogs, small mixed breeds, large mixed breeds, compared to mixed breed dogs of unspecified size), and BCS (ordinal: 3, 5, 7, 9 compared to 1). Variables were assessed for correlations and collinearity prior to inclusion in the final model, no collinearity correction was required. Using backward stepwise elimination to remove non-significant variables, the final model included dog age, age squared, sex status, breed type and diet. Model fit was visually evaluated by assessment of distribution of the residuals.

Logistic regression models were designed to assess the relationship between individual health disorders and diet. One model was developed for each individual health disorder as the dependent variable (cardiac, dental, dermatological, endocrinological, GI and hepatic, neoplastic, neurological, obesity, ocular, renal and urinary), measured as a binary present/absent outcome. Independent variables considered included dog diet (MB, PB, PB + MB/H), dog age, sex, sex status, breed type, and BCS. Variables were assessed for correlations and collinearity prior to inclusion in the model, no corrections for collinearity were required. Backward stepwise regression was used to eliminate non-significant variables from the final multivariate model for each health disorder. Significant independent variables kept in each multivariate model differed based on health disorder (Table 6). Though non-significant for some disorders, age was forced into the model due to the known associations between increasing age and risk of health disorders as was diet, as it was the variable of interest. Model fit was assessed by Hosmer-Lemeshow goodness-of-fit test.

Ordered logistic regression modelling was used to evaluate the relationship between owner perception of dog heath, ranked in four levels: "poor", "fair", "good", and "very good". The dependent variable was health ranking, with odds ratios reported in comparison to the referent outcome "very good". Independent variables considered included dog diet (MB, PB, PB + MB/H), dog age, sex, sex status, breed type and BCS. Variables were assessed for correlations and collinearity prior to inclusion in the model, no collinearity corrections were required. Backward stepwise regression was used to eliminate non-significant variables from the final multivariate model. Significant independent variables kept in the final multivariate model were dog age, sex and diet.

For all analyses, statistical significance was set at $P < 0.05$. A-priori sample size estimations were made using data regarding prevalence of canine health disorders (O'Neill et al., 2014; Lund et al., 1999). Considering the suggested increased risk of urinary tract diseases in dogs fed PB diets (Knight and Leitsberger, 2016), this health disorder was chosen for sample size estimation. Assuming the proportion of dogs fed MB with urinary tract disorders was 3%, calculation of the sample size comparing two different proportions yielded a required sample size of 171 dogs per group. Post-hoc power calculations were performed comparing the mean values or proportions of each variable of interest between diet groups, considering an α value of 0.95 and a β of 0.8 as the cut-off points. Power <80% was considered too low and represented an insufficient sample size to detect significant ($P < 0.05$) differences.

2.5. Response rate and demographic information

A total of 1413 questionnaires were undertaken and included for analysis. Partially completed surveys were included, thus the number of responses for each question varied as a result of non-responses to individual questions. Demographic data of respondents are shown in Table 1. Post-hoc power calculations confirmed the sample size was adequate to attain statistical significance for comparison between dogs fed different diets.

Nearly twice as many respondents kept dog(s) only (916/1383, 65%) when compared to those who kept dog(s) and cat(s) (497/1413, 35%). The median number of dogs kept per respondent was one (range 1–13). Most dogs were acquired from shelters, rescues or veterinarians (601/1344, 45%), followed by purchase from registered breeders (347/1344,

Table 1
Respondent demographics as reported by participants in the "Pet Health and Wellbeing" survey.

		n = 1413	%
Country	Canada	1000	71
	United States of America	413	29
Gender	Female	1208	86
	Male	170	12
	Prefer not to disclose	29	2
Age	<18 years	19	1
	18–24	163	12
	25–34	327	23
	35–44	279	20
	45–54	299	21
	55–64	212	15
	65–74	86	6
	75–84	9	1
	>85 years	0	0

26%), inherited or gifted from friends and family (132/1344, 10%) or purchased online (136/1344, 10%). Less commonly, dogs were purchased from backyard breeders, farms, or homebred (98/1344, 7%) or from pet stores (30/1344, 2%). Most dogs were acquired by respondents at puppyhood (786/1307, 60%), with less than half acquired later in their life (523/1307, 40%), and had been kept by the respondents for 2 weeks to 18 years (mean 5.1 years, std. dev.3.9).

2.6. Dog characteristics

A summary of dog characteristics is shown in Table 2, grouped by diet type. One hundred and eighteen specific breeds were reported, available in Table S1. An additional 162 named crossbreeds were also reported, the rest were mixes or unknown. Median dog age was six years, with a range from four months to 18 years. There were no associations between dog diet or breed type and dog age. Most dogs lived indoors with controlled access to the outdoors (1156/1351, 86%), some had uncontrolled access to the outdoors (184/1351, 14%), and few lived outdoors exclusively (11/1351, 0.8%). The majority of respondents indicated that their dogs did not hunt prey (1184/1350, 88%). Some dogs were reportedly capable of hunting, though their owners did not believe they did so (106/1350, 7.9%), and few were known to hunt prey (60/1350, 4.4%).

3. Results

3.1. Dog diet

Diet information was collected for 1189 dogs, with half (665/1189, 56%) being fed MB, a third (357/1189, 30%) being fed strictly PB, and few being fed a combination of PB with MB (63/1189, 5%) or indeterminable (104/1189, 9%). Dogs fed a PB diet but known to hunt prey were re-categorized as PB + MB/H for health outcome comparisons, reducing the number of plant-based dogs to 339, and increased the number of PB + MB/H to 81. Table 2 shows a summary of dog feeding practices, by dog demographic. Just over half of dogs were reported to receive treats (710/1196, 59%), while half also received table scraps (595/1195, 50%) in addition to their main diet. Significantly ($P < 0.001$) fewer dogs fed PB received treats (175/357, 49%) as compared to dogs fed MB (440/665, 66%). There were no differences in feeding of table scraps, though the types of table scraps differed. Regardless of overall diet, the most common scraps given to dogs were fruits and vegetables (199/665, 30% MB vs 156/357, 44% PB). Aside from fruits and vegetables, among the dogs fed MB, meat scraps were most commonly offered (118/665, 18%), followed by eggs and dairy (92/665, 14%). Among the dogs fed PB, nuts, seeds and legumes were common scraps (43/357, 12%), followed by grain products like pasta, bread, rice and ancient grains (38/357, 11%). Supplements were given to a quarter of dogs (315/1189, 26%). Among the 315 dogs given supplements, the median number of supplements per dog was 1, with a range from 1 to 7. Supplement use varied significantly between diet groups, with 33% of PB (119/357) compared to 25% of MB (165/665) dog receiving supplements ($P = 0.002$). The most common supplements

Table 2
Characteristics of dogs as reported by participants in the "Pet Health and Wellbeing" survey.

Dog characteristic		MB		PB		PB + MB	
		n = 665	%	n = 357	%	n = 63	%
Sex	Male (n = 679)	317	48	174	49	38	60
	Female (n = 688)	347	52	181	51	25	40
Sex status	Intact (n = 150)	86	13	29	8.2	5	7.9
	Desexed (n = 1214)	577	87	326	92	58	92
Age (years)	<1 (n = 59)	36	5.6	6	1.7	5	8.3
	1–2 (n = 224)	129	20	41	12	9	15
	3–4 (n = 206)	114	18	41	12	11	18
	5–6 (n = 221)	92	14	72	21	10	17
	7–8 (n = 206)	88	14	65	19	4	6.7
	9–10 (n = 178)	72	11	51	15	5	8.3
	11–12 (n = 118)	57	9.0	33	9.5	9	15
	13–14 (n = 74)	35	5.5	25	7.2	4	6.7
	15 and greater (n = 35)	14	2.2	14	4.0	3	5.0
Breed type	Toy (n = 168)	75	11	51	14	5	7.9
	Retrievers (n = 105)	70	11	17	4.8	1	1.6
	Collies and herding dogs (n = 66)	40	6.0	13	3.7	3	4.8
	Terriers (n = 60)	35	5.3	12	3.4	3	4.8
	Shepherds and livestock dogs (n = 60)	35	5.3	9	2.5	1	1.6
	Working and hunting dogs (n = 65)	35	5.3	14	3.9	2	3.2
	Scent hounds (n = 37)	19	2.9	13	3.7	1	1.6
	Mastiffs and bulldogs (n = 61)	25	3.8	14	4.8	5	7.9
	Nordic breeds (n = 30)	19	2.9	13	3.7	1	1.6
	Sighthounds (n = 23)	11	1.7	4	1.1	1	1.6
	Spitz and primitive dogs (n = 16)	9	1.4	6	1.7	0	0
	Small cross (n = 186)	76	11	57	16	13	21
	Medium cross (n = 166)	81	12	46	13	7	11
	Large cross (n = 244)	107	16	68	19	13	21
	Unknown mix (n = 69)	32	4.8	24	6.7	5	7.9

Note: numbers of dogs per category may not add up to total due to non-responders and indeterminable diet type.

given to dogs fed MB (165/665, 25%) were sources of omega-3 fatty acids, glucosamine, chondroitin and ingredients indicated for joint health (107/665, 16%) and vitamins, minerals or coenzymes (44/665, 6.6%). Supplements offered more commonly to dogs fed PB (119/357, 33%) were vitamins, minerals or coenzymes (47/357, 13%), yeast (36/357, 10%), or nuts and seeds (26/357, 7.3%). Supplement use was also variable dependent on food processing, used by 24% of owners feeding commercial heat-processed diets, 41% feeding commercial or homemade raw MB diets, and 54% feeding cooked or raw homemade diets. Supplement use differed significantly ($P = 0.006$) with presence of health disorders. Provision of dietary supplements increased with reporting of health disorders, ranging from 23% (112/482) in dogs with no health disorders to 41% (14/34) in dogs with 4+ disorders. The odds of using one or more supplements were 1.2 times higher per disorder present. Specifically, supplement use was significantly higher for dogs with dermatological (78/247, 32%, $P = 0.04$) and musculoskeletal (48/100, 48%, $P < 0.001$) disorders.

Diet selection was primarily based on whether a diet was complete and balanced (852/1184, 72%), all selection criteria are shown in Table 3 and compared between dog diets. Significant differences were found between feeders of MB and PB diets regarding specific ingredients they wished to avoid or they particularly wanted included in their dog's food. Among the MB feeders, avoiding grains (64/661, 9.7%) or specific animal ingredients (52/661, 7.9%) were most common. Among the PB feeders, avoiding all animal ingredients (350/357, 98%) or grains (12/357, 3.4%) were most common. Respondents not only indicated what their selection criteria were, but they also ranked the importance of their chosen selection criteria (Fig. 1). Respondents indicated the resources they used for information about canine nutrition. Veterinary professionals (802/1106, 68%), and the internet (765/1106, 65%) were equally the most common reported sources of canine nutrition information, though proportion varied by diet (Table 4). Owners feeding PB relied more on the internet (285/357, 80%) while owners feeding MB relied more on veterinarians (498/664, 75%).

Dogs had reportedly been fed their current diet for their whole life (650/1205, 54%) or had changed diet at least once prior to being fed their current diet (555/1205, 46%). On average, dogs had been fed their current diet for 3 years (range 0.05–15 years). There was no difference in duration of feeding between dogs fed MB (median 3 years, range 0.05–18) or PB (median 3 years, range 0.05–16). Of the dogs fed a PB diet, 20% (72/357) had unsupervised access to the outdoors and 12% (42) were reported to be capable of hunting prey, while 5.3% were known to hunt (19/357) and could thus supplement their otherwise plant-based diet with prey.

Table 3
Factors influencing pet food purchasing as reported by participants in the "Pet Health and Wellbeing" survey, with comparison between owners of dogs fed different diets.

Criteria	Total		MB		PB		PB + MB	
	n = 1184	%	n = 661	%	n = 357	%	n = 63	%
Complete and balanced	852	72	488	74	251	70	47	75
Convenience	337	28	196	30	98	27	19	30
Homemade	174	15	70	11[a]	84	24[b]	10	16[a,b]
Human grade	433	36	226	34	142	40	33	52
Natural/organic/holistic	375	32	153	23[a]	156	44[b]	32	51[b]
Palatability	282	24	177	27	68	19	15	24
Presence/lack specific ingredient	181	15	135	20[a]	20	5.6[b]	9	14[a,b]
Price	315	27	190	29	71	20	20	32
Raw	128	11	124	19[a]	0	0[b]	2	3.2[a,b]
Skin/coat health	318	27	202	31[a]	68	19[b]	21	33[a]
Stool quality/odour	204	17	133	20	53	15	10	16
Therapeutic/vet recommended	100	8.5	86	13	3	0.8	3	4.8

Superscript characters denote significant ($P < 0.05$) differences between the diet categories.
Note: values add up to >100% since respondents could indicate that they sought information from more than one source and numbers of dogs per category may not add up to total due to non-responders and indeterminable diet type.

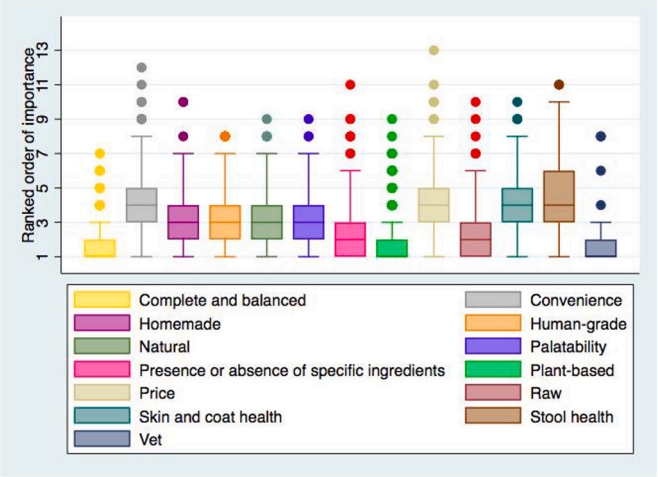

Fig. 1. Box and whisker plot demonstrating importance of each reported criterion for diet selection, ranked from 1 (most important) to 13 (least important). Responses closest to 1 were most important, further from 1 were less important.

Table 4
Resources used to acquire canine nutrition information as reported by participants in the "Pet Health and Wellbeing" survey, with comparison between owners of dogs fed different diets.

Source of information	Total		MB		PB		PB + MB	
	n = 1186	%	n = 664	%	n = 357	%	n = 63	%
Book, pamphlet or printed resource	247	21	16	25	82	23	16	25
Breeder, trainer or groomer	86	7	80	12	2	0.6	1	1.6
Discussion group	345	29	185	28	116	32	16	25
Friends and/or family	233	20	130	20	63	18	11	17
Internet and social media	765	65	368	55[a]	285	80[b]	47	75[a,b]
Pet food vendor or manufacturer	239	20	161	24	46	13	10	16
Education or experience	59	5.0	43	6.5	12	3.4	3	4.8
Veterinary technician, practitioner, specialist, student	802	68	498	75[a]	194	54[b]	41	65[a,b]

Superscript characters denote significant ($P < 0.05$) differences between the diet categories.
Note: values add up to >100% since respondents could indicate that they sought information from more than one source and numbers of dogs per category may not add up to total due to non-responders and indeterminable diet type.

3.2. Dog health and wellbeing

Owners reported a dog BCS ranging from 1 to 9, with most owners reporting their dogs to be in ideal condition (679/1187, 57%). More

owners reported their dogs to be overweight (312/1187, 26%) than underweight (196/1187, 17%). There were no significant differences in owner-reported BCS based on diet type. Based on Kruskal Wallis test, there were significant differences in BCS based on breed type, with the lowest BCS (mean BCS 4, Std. Dev. 1.6) for sighthounds and the highest (mean BCS 5.6, Std. Dev. 1.3) for retrievers (P = 0.0001). Mean owner-reported faecal score was 2.6 (Std. Dev. 1.05) on a scale from 1 to 7. There were significant (P = 0.02) differences in faecal score depending on diet, with fewer owners of dogs fed PB reporting constipation (0/336, 0% vs 8/652, 1.2%) or hard faeces (178/318, 56% vs 431/652, 66%), and more reporting slightly soft faeces (44/318, 14% vs 51/652, 7.8%) in comparison to dogs fed MB.

Health disorders were reported by the dog owners and categorized by body system or as systemic disorders, as appropriate. The number of owner-reported disorders per dog ranged from 0 to 7 (mean 0.97, Std. Dev. 1.17), with nearly half of all dogs (624/1413, 44%) having no reported health disorders. Age was positively associated with the number of health disorders reported, with every year of age increasing the number of health disorders by 0.08 (P < 0.001). Difference in number of owner-reported health disorders were also detected by breed type, with toy breeds, retrievers, scent hounds, terriers, mastiffs and bulldogs, working and hunting dogs, sighthounds, small crossbreeds and large crossbreeds having more health disorders than mixed breed dogs. A negative binomial regression was designed to investigate the association between diet and number of health disorders, including potential confounders age, age squared, sex status and breed type in the model. In comparison to owners of dogs fed a MB diet, owners of dogs fed strictly PB reported 0.13 (95% CI 0.03–0.22) fewer health conditions (P = 0.009). Prevalence of the most common health disorders reported are shown in Table 5. Logistic regression was used to investigate diet and specific health disorders, with potential confounders age, sex, sex status, and dog type also included in the models (see Table 6). Owners of dogs fed plant-based diets had reduced odds of reporting GI and hepatic or ocular disorders in their dogs.

Owners also ranked their dog's health from poor to very good. The majority considered their dog's health to be very good (849/1187, 72%), regardless of diet (PB 268/338, 80%; MB 459/665, 69%). Indices of wellness were also reported (Table 7).

Table 5
Prevalence of canine health disorders as reported by participants in the "Pet Health and Wellbeing" survey, with comparison between dogs fed different diets.

Health disorder	Total		MB		PB		PB + MB/H	
	n = 1171	%	n = 656	%	n = 339	%	n = 81	%
Cardiac disease	29	2.4	14	2.1	11	3.2	3	3.7
Dental disease	232	20	128	19	65	19	15	19
Dermatopathy	245	21	132	20	63	19	21	26
Endocrinopathy	21	1.8	16	2.4	5	1.5	0	0
Gastrointestinal and hepatic diseases	145	12	96	15	26	7.8	9	12
Lower urinary tract disease	61	5.2	32	4.9	19	5.7	5	6.3
Neoplasia	36	3.0	20	3.0	13	3.8	2	2.5
Neurological	48	4.1	28	4.3	10	3.0	5	6.2
Obesity	43	3.7	22	3.4	14	4.2	5	6.3
Ophthalmic disorders	100	8.5	67	10	23	6.8	5	6.2
Renal disease	14	1.2	12	1.8	0	0	1	1.3

MB = meat-based, PB = plant-based, PB + MB/H = plant-based with animal-derived treats/snacks/supplements and/or ability to hunt.
The numbers of dogs per category may not add up to total due to non-responders and indeterminable diet type.

Table 6
Results from multivariable logistic regression models (one model for each disorder) of associations between reporting of health disorders and dog diet, after controlling for confounders (age, breed type, sex, sex status).

Health disorder	Variable	Odds ratio	95% CI	P-value
Cardiac	Age	1.17	1.068–1.285	0.001
	Diet, PB	–	–	0.431
	Diet, PB + MB/H	–	–	0.363
Dental	Age	1.16	1.116–1.212	< 0.001
	Breed type, toy	6.77	1.968–23.287	0.002
	Breed type, scent hound	7.04	1.764–28.122	0.006
	Breed type, terrier	4.11	1.065–15.886	0.040
	Breed type, spitz	11.16	2.323–53.609	0.003
	Breed type, small mix	5.32	1.546–18.323	0.008
	Diet, PB	–	–	0.147
	Diet, PB + MB/H	–	–	0.634
Dermatological	Age	1.07	1.027–1.109	0.001
	Sex status, intact	0.34	0.162–0.719	0.005
	Diet, PB	–	–	0.374
	Diet, PB + MB/H	–	–	0.277
Endocrine	Age	1.23	1.104–1.381	< 0.001
	Diet, PB	–	–	
	Diet, PB + MB/H	–	–	0.247
GI and hepatic	Diet, PB	0.57	0.358–0.900	0.016
	Diet, PB + MB/H	–	–	0.727
Lower urinary tract	Age	1.10	1.029–1.174	0.005
	Sex, male	0.28	0.147–0.550	< 0.001
	Diet, PB	–	–	0.747
	Diet, PB + MB/H	–	–	0.397
Neoplasia	Age	1.26	1.151–1.381	< 0.001
	Diet, PB	–	–	0.946
	Diet, PB + MB/H	–	–	0.383
Neurological	Age	1.18	1.088–1.272	< 0.001
	Breed type, sight hound	7.74	1.587–37.736	0.011
	Diet, PB	–	–	0.287
	Diet, PB + MB/H	–	–	0.287
Obesity	Age	1.13	1.028–1.205	0.008
	Diet, PB	–	–	0.652
	Diet, PB + MB/H	–	–	0.569
Ocular	Age	1.10	1.039–1.158	0.001
	Breed type, toy	3.06	1.374–6.822	0.006
	Diet, PB	0.53	0.315–0.898	0.018
	Diet, PB + MB/H	–	–	0.464
Renal	Age	1.16	1.019–1.316	0.024
	Diet, PB	–		
	Diet, PB + MB/H	–	–	0.666

Referent categories: Breed type = mixed breed, Diet = meat-based, sex = female, sex status = desexed. For non-significant variables '-'replaces the OR and CI.

3.3. Dog lifespan

Respondents were asked about previous dogs, with indicated lifespans ranging from 8 months to 23 years (median 13 years). The diets fed to previous dogs were MB (907/1201, 76%), PB (103/1201, 8.6%), a combination of PB with MB (42/1201, 3.5%) or indeterminable (149/1201, 8.8%). Previous dogs reportedly fed a PB diet had significantly (P < 0.01) longer lifespan than dogs fed MB (mean 14.1 years, 95% CI 13.5–14.7 vs mean 12.6 years 95% CI 12.3–12.8, respectively) (Fig. 2).

4. Discussion

The convenience sampling strategy employed was successful in targeting owners feeding PB to their dogs. The proportion of owners feeding PB diets in this study, 30%, was greater than what has been estimated for the general pet-keeping population, previously

Table 7
Responses to seven Likert scale questions asking respondents to rank indices of dog wellness, with comparison between dogs fed different diets.

Wellness indicator		Total		MB		PB		PB + MB/H	
		n = 1105	%	n = 605	%	n = 324	%	n = 79	%
Frequency of vomiting	Not at all	852	77	456	75	256	79	66	84
	A little	249	23	147	24	67	21	12	15
	Quite a bit	4	0.4	2	0.3	1	0.3	1	1.3
Frequency of inactivity	Not at all	866	78	462	76	268	83	63	81
	A little	207	19	127	21	45	14	13	17
	Quite a bit	32	2.9	17	2.8	10	3.1	2	2.6
Happy appearance	Not at all	1	0.1	0	0	0	0	1	1.3
	A little	12	1.1	8	1.3	3	0.9	1	1.3
	A moderate amount	243	22	129	21	72	22	16	21
	A great deal	841	77	464	77	246	77	59	77
Distress vocalization	Not at all	757	69	413	69	216	67	55	71
	A little	281	26	151	25	90	28	18	23
	A moderate amount	47	4.3	4	5.2	13	4.0	4	5.2
	A great deal	13	1.2	8	1.3	3	0.9	0	0
Demonstration of affection	Not at all	0	0	0	0	0	0	0	0
	A little	12	1.1	7	1.2	3	0.9	1	1.3
	A moderate amount	200	18	109	18	61	19	12	16
	A great deal	885	81	485	81	257	81	64	83
Contact avoidance	Not at all	932	85	508	85	276	86	64	83
	A little	154	14	86	14	42	13	12	16
	A moderate amount	11	1.0	6	1.0	4	1.2	1	1.3
	A great deal	1	0.1	1	0.2	0	0	0	0
Curious behaviour	Not at all	14	1.3	8	1.3	1	0.3	2	2.6
	A little	68	6.2	40	6.7	19	5.9	5	6.5
	A moderate amount	369	34	200	33	110	34	22	29
	A great deal	646	59	352	59	192	60	48	62

MB = meat-based, PB = plant-based, PB + MB/H = plant-based with animal-derived treats/snacks/supplements and/or ability to hunt.

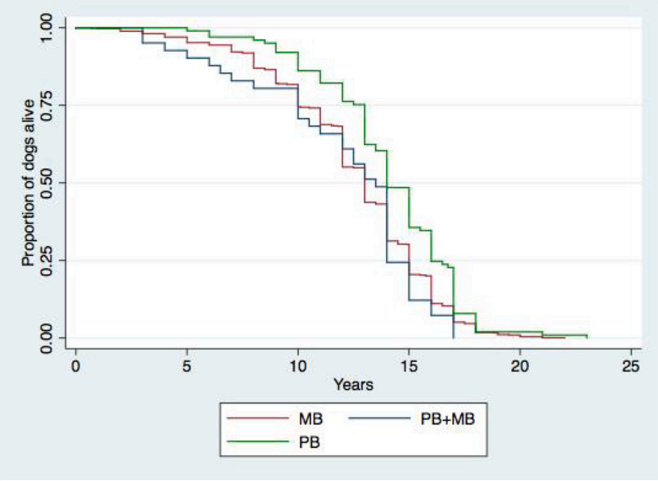

Fig. 2. Kaplan-Meier survival plot depicting lifespan of previously owned dogs as reported by owners, comparing dogs fed plant-based (PB, n = 103), meat-based (MB, n = 907) or a combination (MB + PB, n = 42) diets.

documented by this research group around 2% (Dodd et al., 2019a). This was expected, as the study was not intended to document the prevalence of particular pet feeding practices, but to compare the owner-reported perceived health and wellbeing of dogs fed PB and MB diets. The convenience sample strategy targeting PB feeders was utilized to obtain a comparable sample size between PB and MB diet feeders. When compared to previous reports, participants in this survey were typical of the demographic of pet food and pet health survey respondents (Dodd et al., 2019a; Morgan et al., 2017; Rajagopaul et al., 2016). Furthermore, dog keeping characteristics, including number of dogs and indoor/outdoor lifestyle, as well as dog characteristics such as median age, sex and sex status, were similar to previous publications from Canada, the United States of America and worldwide (Pugh et al., 2015; Heuberger and Wakshlag, 2011; Wan et al., 2009).

Aside from the previously mentioned high prevalence of PB feeding, the feeding practices documented here are comparable to other recent reports (Stull et al., 2013; Connolly et al., 2014; Dinallo et al., 2017; Dodd et al., 2020). The feeding of treats and table scraps was expected, though daily intake from treats and scraps could not be quantified. The risk this posed to unbalancing a complete diet could thus not be estimated, though a lack of correlation between treat/scrap feeding and BCS or health disorders would suggest this practice did not pose a significant risk. The proportion of fed supplements was lower in this study population as compared to previous estimates, though the range of supplements fed per dog and the proportion of supplement types were similar (Bianco et al., 2020). Supplementation of vitamins and minerals is indicated when homemade diets are being fed, but were reported by only half of the respondents feeding a homemade diet. Commercial diets labelled for growth or maintenance sold in the USA and Canada are typically formulated or undergo feeding trials to ensure they meet the nutritional requirements of dogs and are considered to provide complete and balanced nutrition for the lifestage and species to which they are intended to be fed (FDA, 2020). Feeding of additional vitamins and minerals in combination with commercial diets, as practiced by nearly 10% of study respondents, may actually be counterproductive and could induce toxicities or interactions between excess vitamins and other nutrients. For example although supplementation up to five times the recommended allowance has been demonstrated to be safe in dogs with vitamin D deficiency (Young and Backus, 2016), clinical hypervitaminosis D has been reported in dogs when their diet contained large excess (Mellanby et al., 2005). The higher prevalence of supplementation of vitamins and minerals in dogs fed PB diets suggests that those owners either have concerns about the vitamin and mineral content of PB diets for dogs, or that there is a perceived benefit of additional vitamin and/or mineral supplementation. Previous work has demonstrated that 60% of vegan pet owners did have concerns that a PB diet would provide incomplete nutrition (Dodd et al., 2019a), so it is possible the higher prevalence of vitamin and mineral supplementation, as compared to feeders of MB diets, reflects an attempt to balance the diet. Alternatively, it may reflect vegans' behaviours regarding their own diet, as the majority of vegans supplement their daily intake with a vitamin

supplement, over five times more than the general population (Vollmer et al., 2018).

In addition to vitamins and minerals, dogs were also given fatty acids, amino acids and their derivatives and herbal supplements. Over-supplementation of fatty acids for anti-inflammatory effects and joint or coat health may also have adverse effects, such as altered platelet function, vomiting, diarrhoea, pancreatitis, altered wound healing, lipid peroxidation, and altered immune function (Lenox and Bauer, 2013). Excessive doses of amino acids and amino acid derivatives can also have adverse effects, ranging from mild gastrointestinal upset to death (Gwaltney-Brant et al., 2000). Even herbal remedies, which pet owners often believe are safe and natural products, are not without risk and severe to life-threatening toxicities are possible (Ooms et al., 2001; Means, 2002; Poppenga, 2001). Furthermore, some supplements that may be safe when fed to healthy pets, could be counter-productive and provide excess nutrients when given with the intention of treating particular health (Shmalberg et al., 2013). Considering that dogs with health disorders were more likely to receive dietary supplements than healthy dogs, this could pose a very real risk to dog health.

The most frequently reported criterion for diet selection was the labelling of the diet as being complete and balanced, and it was also valued as the second most important criterion (Fig. 1). The most important criterion was veterinary recommendation. Of all the criteria reported by dog owners, complete and balanced and veterinary recommendation are the two criteria which relate most to the suitability of the diet for the animal, while most of the other criteria relate to the suitability of the diet for the owner. This suggests dietary choices are being made with the best interest of the animal as a top priority, which is not surprising, considering the role of dogs as family members (Case, 2008) and previous research regarding the prioritization of dog nutrition (Kamleh et al., 2020). The resources dog owners are using to educate themselves about canine nutrition are shown in Table 4 and it can be seen that veterinary professionals and the internet are similarly indicated. Among dog owners feeding MB, veterinarians outweigh the internet considerably, though among those feeding PB, the inverse relationship was seen. It is recognized that veterinary clinics may provide some nutrition-related information on their website, and veterinary professionals also run social media websites and blogs regarding nutrition. These resources were not differentiated from other internet resources in this study, thus, it is possible for the internet and veterinary categories to overlap. Nevertheless, the inverse relationship between internet and veterinary professional reported by PB vs MB feeders is interesting. It has been demonstrated that feeders of diets considered unconventional or alternative may have less trust in veterinary professionals as a source of nutritional information (Morgan et al., 2017). This phenomenon likely includes feeders of PB diets, as only 20% of vegans regarded veterinary approval as being an important factor in determining whether or not they would consider feeding their pet a PB diet (Dodd et al., 2019a). Of note, neither diet group reported high usage of pet food manufacturers or distributors as sources of information regarding canine nutrition. Whether this indicates a lack of trust in the pet food industry, as has been previously suggested (Sprinkle, 2018), or whether pet owners make some decisions about pet food purchases based on information acquired prior to going to a store or online retail site could not be determined from this data.

With respect to the impact of diet on health and wellbeing, it must be noted that very few nutritionally-associated outcomes arise rapidly, particularly in adult animals, and thus long-term feeding of a diet is typically required in order to see a response or change in a given parameter. In young, growing puppies, nutritional imbalances and inadequacies can rapidly manifest with severe clinical signs (Dodd et al., 2019b; Hutchinson et al., 2012; McMillan et al., 2006; Tal et al., 2018). However, in adult dogs, these can take months to years to develop prior to diagnosis (Verbrugghe et al., 2011; de Fornel-Thibaud et al., 2007). Thus, the duration of feeding was an important factor to extrapolate any association between diet and health. Half of dogs had been fed their current diet for as long as they had been owned, with the median duration of ownership being 4 years. The median duration of feeding the current diet was also 3 years. Association between health status and diet of the participants' dogs was therefore considered possible, as much as could be attributed to diet.

The proportion of dogs reported to be ideal body condition (57%) is likely an overestimation, as the proportion of dogs reported to be overweight (26%) is likely an underestimation. In 1995, the prevalence of overweight and obesity among US dogs was close to the findings of the current study (Lund et al., 2006), but has been trending upwards since then (Chandler et al., 2017). A survey of American veterinary clinics in 2018 found that, based on veterinary assessment of BCS, only 43.1% of dogs were ideal, 55.8% were overweight (36.9%) or obese (18.9%), only 1.1% were underweight (Ward, 2019). This discrepancy was expected, to a degree, as it has been previously described that pet owners fail to appropriately identify overweight conditions in their pets (White et al., 2011) and that untrained evaluators tend to underestimate BCS (Shoveller et al., 2014). So, while the overall reporting may be an underestimation of the true BCS, the factor of most interest in this study was a comparison of the owner-reported BCS between dogs fed MB and PB diets. In humans, a difference in body composition has been reported between vegans and non-vegans, with vegans being leaner with a lower body mass index (Rosell et al., 2006; Le and Sabaté, 2014; Berkow and Barnard, 2006; Melina et al., 2013), and a PB diet being recommended for treatment and prevention of obesity (Turner-McGrievy et al., 2017; Kahleova et al., 2018; Wright et al., 2017). The same was not found for dogs, with no difference in BCS attributable to diet, suggesting that PB diets do not protect against overweight in dogs. However, BCS was not confirmed in the study, relying on owner-reporting.

Overall the reported faecal consistency was firmer than is considered normal, with the majority of respondents indicating a faecal score of 2, which is considered slightly harder and drier than ideal. Whether these dogs were truly exhibiting abnormal faeces, or whether this represents a challenge using pictographic faecal scoring systems with untrained pet owners could not be determined. However, it is interesting to note that dogs fed PB were reported to have softer stool than dogs fed MB, with more faecal scores consistent with normal stool. This may be attributable to the greater presence of dietary fibre in plant ingredients compared to animal ingredients, as fibre has noted effects on faecal consistency (Jackson and Jewell, 2019; Propst et al., 2003; Fritsch et al., 2019).

In this study, results relied on owner reporting of perception of health, no review of medical records or confirmatory examination could be performed. The proportion of dogs with one or more health disorders reported by the owner was greater in this study than has previously been documented by other surveys of pet owners (Heuberger and Wakshlag, 2011; Freeman et al., 2006). The data captured by this study includes conditions that dogs may have had in the past, but have overcome, as opposed to including only disorders affecting them at the present time. Conversely, as expected, the proportion of dogs with health disorders was lower than what is reported for dogs attending veterinary clinics, as the majority of visits to veterinary clinics are as result of a health disorder (Lund et al., 1999). The prevalence of specific conditions, however, was comparable to data collected from primary healthcare facilities, with dental disease and dermatopathies most commonly reported (O'Neill et al., 2014; Lund et al., 1999). As noted above, the prevalence of obesity reported in this study is likely an underestimation. Nevertheless, the number of dogs reported to be obese did agree somewhat with the number of dogs reported to have a BCS of 9, suggesting that owners did recognize such an extreme degree of overweight as being a pathological condition, though owners of overweight dogs with a BCS of 7–8/9 did not appear to recognize those BCS as obesity. Prevalence of health conditions varies among dog breed types. It has been documented that mixed breed dogs live longer than purebred counterparts (Yordy et al., 2020), and in the UK had significantly lower prevalence of obesity and dermatological and ophthalmological

disorders than purebred dogs (O'Neill et al., 2014). In the present study as well, owners of mixed breed dogs reported a lower number of health disorders.

Interestingly, dog owners reported fewer disorders per dog fed PB than MB diets. Specifically, an association between dogs fed PB and reduced odds of ocular or GI and hepatic disorders was detected. Further, more owners feeding their dog PB considered their dog to be in very good health as compared to owners feeding their dog MB. Whether this reveals dogs fed PB truly have better health, or that owners are biased in their perceptions, and those feeding PB had a more positive perception of their dogs' health could not be determined. Previously, it has been reported that vegetarians (of which 17% were vegan) had more positive attitudes towards pet animals as compared to non-vegetarians (Preylo and Arikawa, 2008). Based on the previous finding that pets being fed PB were almost all owned by vegans, and the remainder by vegetarians (Dodd et al., 2019a), it was assumed that a majority of dogs fed PB in the present study were owned by vegans or vegetarians, and it is possible this increased positive perspective on dog health may be attributable in part to a more positive attitude towards the dog in general. Furthermore, meat-avoidance has been associated with a more 'health conscious' identity and improved perception of health, which vegetarian or vegan pet owners may be applying to their pet as well (Bedford and Barr, 2005; Corrin and Papadopoulos, 2017). These dog owner attitudes and beliefs should be considered by veterinary practitioners when discussing diet and health with owners of dogs fed PB diets.

An alternative possibility is that upon diagnosis with a health condition, the diet of dogs may have been changed on recommendation of a veterinary practitioner. Thus, it is possible that dogs previously fed a PB diet may have been switched to a meat-containing diet, thus giving the erroneous appearance that fewer dogs fed PB diets suffer from GI-related disorders, although a change from a meat-based to a plant-based therapeutic diet may also be recommended by veterinary practitioners. Some veterinary therapeutic diets are indicated for adverse food reactions, chronic gastrointestinal disease, exocrine pancreatic insufficiency, food allergic dermatitis, food allergic gastroenteritis, food intolerance, hepatic encephalopathy, hyperlipidemia, inflammatory bowel disease, liver disease, lymphangiectasia, malabsorption, pancreatitis, protein-losing enteropathy and urate and cystine urolith prevention are plant-based[a,b], though most therapeutic diets indicated for canine health conditions are meat-based.

Based on owner reporting of the lifespan of their previously-owned dogs, longevity reported in this study is in close agreement with other studies (O'Neill et al., 2014; Galis et al., 2007; Kahleova et al., 2018; Adams et al., 2016). Interestingly, despite the lack of differences in perceived health detectable among the respondents' current dogs, diet had a significant association with lifespan, with dogs fed PB reportedly living 1.5 years longer. It must be recognized that a retrospective survey collecting owner-reported data based on their recollection of information does not provide the same level of evidence as a prospective paired cohort lifetime study. However, it does present an interesting insight, if accurate. In humans, aside from prevention and treatment of certain diseases, including obesity, cardiovascular disease and diabetes, a PB diet has also been proposed to slow aging and increase longevity (McCarty et al., 2009). However, the main mechanism by which this is proposed is via a reduced intake of methionine, which may not be translatable to dogs and dog diets, as dietary methionine content must meet a minimum recommended level in order for the product be labelled as complete and balanced for either puppy growth or adult maintenance. In a study investigating the amino acid content of commercial PB dog foods in Canada, the methionine content ranged from 84 to 504% (median 181%) of minimum requirements according to the National Research Council (AAVN, 2020). This doesn't support the idea of PB diets increasing longevity as a consequence of low provision of methionine. Furthermore, in dogs, methionine restriction may result in insufficient endogenous synthesis of taurine and adverse health outcomes associated with sulfur amino acid and taurine deficiencies (Backus et al., 2006; Fascetti et al., 2003). Alternative theories include the ability of a PB diet to down-regulate insulin-like growth factor I and thus 'slow' the aging process (McCarty, 2003), or to boost production of 'pro-longevity' fibroblast growth factor 21 (McCarty, 2015). Research investigating the effect of PB diets on lifespan in dogs is necessary.

An alternative reason for the owner-reported longer lifespan in dogs fed PB diets could be a delay of euthanasia in aged and end-of-life dogs. The unique perspectives of individual dog owners, with respect to their thoughts, feelings and experiences, may impact decision-making regarding euthanasia of aged and ill dogs (Spitznagel et al., 2020). It was assumed, based on previous research, that the majority of respondents feeding a plant-based diet to their pet followed a vegetarian or vegan lifestyle themselves (Dodd et al., 2019a). It is thus possible that, given the strong affinity of meat-avoiders for companion animals (Rothgerber, 2013; Herzog Jr et al., 1991), that making end of life decisions may be more drawn out, resulting in a longer lifespan. In contrast, vegetarians and vegans may have greater concern for animal suffering and greater empathy for animals (Filippi et al., 2010) when compared to non-vegetarians, which would suggest compassionate consideration of euthanasia when dogs enter end-of-life criteria. More research investigating owner beliefs and feelings towards animals and their decision making surrounding end-of-life and euthanasia are needed.

Being a retrospective, convenience sampled, cross-sectional study, there are limitations to data interpretation inherent due to study design. No causation can be inferred, and there is a high risk of recall bias – particularly for questions regarding previously-owned dogs. Interpretation of the findings must thus be made with these considerations in mind.

5. Conclusion

This study surveyed a sample of dog owners from Canada and the USA to describe the owner perception of health and wellbeing of dogs fed PB and MB diets. No adverse health outcome was associated with feeding PB diets to dogs, indeed feeding of PB diets was perceived to be potentially protective against health disorders, and the lifespan of dogs fed PB was reportedly longer than for dogs fed MB. Owners who fed PB reported a more positive perception of their dogs' health than owners who fed a MB diet. This perception must be considered by veterinary practitioners when diet-related health risks or benefits are discussed with dog owners, particularly as dog owners feeding plant-based may seek information regarding dog diet from alternative resources. Further prospective research is warranted to determine if PB alter canine health.

Conflict of Competing Interest

SD declares that they have participated in paid internships and engagements with various pet food companies within Canada and the USA and are the owner operator of Dodd Veterinary Services. CD and DK declare no conflict of interest. AV is the Royal Canin Veterinary Diets Endowed Chair in Canine and Feline Clinical Nutrition and declares that they serve on the Health and Nutrition Advisory Board for Vetdiet and have received honoraria and research funding from various pet food manufacturers and ingredient suppliers.

The authors wish to acknowledge Allison Lull, a student veterinarian at the Ontario Veterinary College, for her assistance with data management, and Mikhail Goussev and Eric Weisman in distribution of the questionnaire to their client base. This study was funded through a Mitacs Accelerate Grant.

Acknowledgements

The authors wish to acknowledge Mikhail Goussev and Eric Weisman at Vecado for distribution of the questionnaire to their client bases. This study was funded through a Mitacs Accelerate Grant in partnership with

Vecado.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rvsc.2022.06.002.

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