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Functional foods in pet nutrition: Focus on dogs and cats

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A R T I C L E I N F O

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A B S T R A C T

Functional foods provide health benefits if they are consumed on a regular basis as part of a varied diet. In this review, we discuss the availability and role of functional foods in pet nutrition with a focus on dogs and cats. Indeed, functional foods modify gastrointestinal physiology, promote changes in biochemical parameters, improve brain functions and may reduce or minimize the risk of developing specific pathologies. This evidence derives largely from clinical studies while only limited evidence is available from studies in dogs and cats. Therefore, functional food consumption should be further investigated in pet nutrition to understand how dietary interventions can be used for disease prevention and treatment.

1. Background

Novel foods and food components have been identified as "functional" because they provide health benefits beyond the provision of essential nutrients, such as vitamins, minerals, water, proteins, carbohydrates and fats (Hasler, 2000). The role of functional foods has been investigated in dogs (*Canis familiaris*) and cats (*Felis catus*) in order to better understand their metabolism, thus optimising companion animal nutritional and health status (Swanson et al., 2003). After a long history of coexistence, the most common pets in modern societies are dogs and cats. Dogs and cats present significant differences in digestive-related processes but, while cats are carnivorous, dogs appear to be omnivorous like human beings (Bosch et al., 2015). Dogs share some carnivorous traits with cats as both lack salivary amylase, have a short gastrointestinal tract and are unable to synthesize vitamin D (National Research Council, 2006). In contrast, there are 3 genes, AMY2B, MGAM and SGLT1 that have evolved only in dogs during domestication and are involved in starch digestion and glucose uptake (Axelsson et al., 2013). Another characteristic of the dogs digestive system is that they can synthesise several essential nutrients such as niacin, taurine and arginine (Bosch et al., 2015). As far as cats are concerned, they can catabolise and use amino acids as a source of energy for gluconeogenesis (Morris, 2002). Cats have a diet consisting of 52% protein, 36% fat and 12% carbohydrate (Plantinga et al., 2011). Therefore, we have to study pet nutrition considering dogs and cats separately. A human-pet parallel exists as pet owners provide their dogs and cats with alternative foods, such as commercially available "natural", raw food and vegetarian diets as they are considered family members (Michel, 2006). The parallel between humans and animals is further strengthened by the evidence that, similarly to human babies who copy adults' redundant actions (Brugger et al., 2007; Cook et al., 2014; Lyons et al., 2007; Topal et al., 2008), companion animals acquire the wrong eating habits from their owners (Marshall-Pescini et al., 2012). This evidence suggests that understanding pet nutrition is also important to study human nutrition; however, this is not object of this article and has been reviewed elsewhere (Di Cerbo et al., 2014).

Several studies have focused on investigating health benefits of ingredients found in commercially available functional foods in humans; these ingredients may also exert their beneficial effects on dogs and cats but, at least in some cases, have not been investigated yet. The interest in the adequacy of commercially available pet foods has been growing worldwide (Zicker, 2008). Functional foods, strongly appre-

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Table 1
Studies of functional foods and functional food-containing diets in dogs.

Functional food/diet containing functional foods	Health benefits	References
FOS alone or in combination with MOS plus poultry by-product meal, brewers rice, poultry fat, beet pulp, dehydrated egg, sodium chloride, potassium chloride, choline chloride, vitamin premix and mineral premix	↑ ileal immunoglobulin A, ↓ fecal total indole and phenol concentrations	Swanson et al., 2002
Oligofructose	↓ levels of *Clostridium perfringens*	Flickinger et al., 2003
Poultry fat combined with 12% stabilized rice bran Defatted rice bran diet combined with poultry fat, beef tallow, or poultry fat:soybean oil (50:50)	↑ food intake and palatability ↓ plasma phospholipid total monounsaturated fatty acids	Spears et al., 2004
Peas	↓ glycemic index value	Adolphe et al., 2012
104·80 μmol retinol (100,000 IU vitamin A)	↑ bone growth	Morris et al., 2012
Corn, beet pulp, yeast, fish oil, minerals, dried yeast (Bio MOS), FOS, *Yucca schidigera*, Vitamin A (15,000 IU), Vitamin D3 (1080 IU), Vitamin E (180 mg), choline chloride (1000 mg), copper chelate of amino acids hydrate (20 mg), DL-methionine (500 mg), taurine (1500 mg), L-carnitine (500 mg), extract rich in natural tocopherols (44.3 mg), *Rosmarinus officinalis* (0.84 mg), *Grifola frondosa* (270 mg), *Curcuma longa* (263 mg), *Carica papaya* (151 mg), *Punica granatum* (103 mg), *Aloe vera* (92 mg), *Polygonum L.* (82 mg), *Haematococcus pluvialis* (74 mg), *Solanum lycopersicum* (25 mg), and *Vitis vinifera* (19 mg)	↓ Body Condition Score, d-ROMs, hematocrit, and platelets ↑ BAP	Pasquini et al., 2013
Antioxidants, phytotherapic compounds, vitamins, and trace elements	↑ metabolic activity (free thyroxine and testosterone) and a consequent positive effect on fertility and thyroid activity ↑ semen motility and vitality	Ponzio et al., 2013
Fish hydrolyzed proteins, rice carbohydrates, *Melaleuca alternifolia* (0.00343%), *Tilia platyphyllos scapoli et cordata* (0.0147%), *Allium sativum L.* (0.0245%), *Rosa canina L.* (0.098%) and zinc (0.00479%)	↓ mean score intensity of all chronic otitis externa-associated symptoms (occlusion of ear canal, erythema, discharge quantity and odor)	Di Cerbo et al., 2014, 2016
Ascophyllum nodosum, *Cucumis melo*, *Carica papaya*, *Aloe vera*, Astaxanthin from *Haematococcus pluvialis*, *Curcuma longa*, *Camellia sinensis*, *Punica granatum*, *Piper nigrum*, *Poligonum spp.*, *Echinacea purpurea*, *Grifola frondosa*, *Glycine max*, and Omega 3 and Omega 6 unsaturated fatty acids	↑ platelet number and CD4/CD8 ratio, ↓ Treg and Th1 cells	Cortese et al., 2015
Rice carbohydrates, *Grifola frondosa*, *Curcuma longa*, *Carica papaya*, *Punica granatum*, *Aloe vera*, *Polygonum cuspidatum*, *Solanum lycopersicum*, *Vitis vinifera*, *Rosmarinus officinalis*, and an Omega 3 and Omega 6 ratio of 1:0.8	↑ BDNF ↓ d-ROMs	Sechi et al., 2015
Fish meal, propolis (0.0161%), *Salvia officinalis* (0.0087%), egg albumen (lysozyme 0.0078%), dehydrated orange extract (bioflavonoids 0.0077%), *Thymus vulgaris* (0.0127%), and *Ribes nigrum* (0.0040%)	↓ halitosis volatile sulfur compounds (methyl mercaptan, hydrogen sulfide and dimethyl sulfide)	Di Cerbo et al., 2015b
Fish proteins, rice carbohydrates (carbohydrates: 75–80%; starch: 65–70%; beta-glucans: < 0.1%), *Cucumis melo* (300 mg/kg), *Ascophyllum nodosum* (40,000 mg/kg), *Astaxanthin* from *Hematococcus pluvialis* (49 mg/kg), *Aloe vera* (135 mg/kg), *Carica papaya* (135 mg/kg), *Punica granatum* (70 mg/kg), *Camellia sinensis* (70 mg/kg), *Polygonum cuspidatum* (7 mg/kg), *Curcuma longa* (102 mg/kg), *Piper nigrum* (30 mg/kg), zinc (137 mg/kg), and an Omega 3 and Omega 6 ratio of 1:0.8	↓ mean intensity of tear production, conjunctival inflammation, corneal keratinization, corneal pigment density and mucus discharge	Destefanis et al., 2016
Rice carbohydrates, *Punica granatum* (0.0457%), *Valeriana officinalis* (0.026%), *Rosmarinus officinalis* (0.000044%), *Tilia spp.* (0.0635%), tea extract (0.031%) and L-tryptophan (0.0329%)	↑ clinical and behavioral symptoms related to general anxiety	Di Cerbo et al., 2016
Punica granatum (457 mg/kg), *Valeriana* officinalis (260 mg/kg), *Rosmarinus officinalis* (0.44 mg/kg), *Tilia spp.* (635 mg/kg), tea extract (392 mg/kg), and L-tryptophan (329 mg/kg), L-theanine (310 mg/kg), Omega 6 (12.5 g/kg), Omega 3 (16 g/kg), Vitamin A (18,500 UI/kg), E (120 mg/kg), C (250 mg/kg), choline chloride (1000 mg/kg), zinc sulfate monohydrate (137 mg/kg), cupric chelate glycine hydrate (39 mg/kg) and DL-methionine (500 mg/kg)	↑ serotonin, dopamine and β-endorphin plasma concentrations ↓ noradrenaline and cortisol plasma concentrations and d-ROMs	Sechi et al., 2017

BAP, biological antioxidant potential; BDNF, brain-derived neurotrophic factor; d-ROMs, derivatives of reactive oxygen metabolites; FOS, fructooligosaccharides; MOS, mannan-oligosaccharides.

ciated for their health benefits, include fruit and vegetables (Slavin and Lloyd, 2012), botanicals (Guidetti et al., 2016), whole grains (Borneo and Leon, 2012), dietary supplements including pycnogenol, collagen, coenzyme Q10, low-molecular-weight hyaluronic acid, chondroitin sulfate and glucosamine sulfate (Di Cerbo et al., 2015a), beverages (Corbo et al., 2014; Shiby and Mishra, 2013), prebiotics and probiotics (Di Cerbo et al., 2012; Di Cerbo and Palmieri, 2015; Di Cerbo et al., 2013; Iannitti and Palmieri, 2010; Ricciardi et al., 2014; Romano et al., 2014; Blaiotta et al., 2016) [probiotics efficacy in canine and feline welfare has been reviewed elsewhere (Grzeskowiak et al., 2015)]. Most of these functional foods can improve satiety (Delzenne and Kok, 2001; Reimer et al., 2012) and reduce postprandial glucose and insulin concentrations (Delzenne and Kok, 2001), thus reducing diabetes-related comorbities. Inulin and oligofructose, two functional foods, can modify the intestinal microflora in dogs, cats (Hussein et al., 1999) and humans (Van Loo et al., 1999). Dietary fibers, which are commonly found in pet foods (de Godoy et al., 2009), can modify the intestinal microflora by promoting commensal bacteria growth (Tungland, 2003). Decrease in gastric emptying, blood cholesterol concentrations (Brennan and Cleary, 2005), gastric transit time, dilution in diet calorie density as well as increase in satiety (Rebello et al., 2013), glucose uptake rate (Jenkins et al., 2008) and fecal excretion (Wenk, 2001) can also be ascribed to dietary fibers.

Whole grains, whose main sources are wheat, corn, oats, barley and rye (Slavin et al., 2001), are rich in dietary fibers, trace minerals, vitamin B and E (Fardet, 2010), bioactive compounds, e.g. tocotrienols, lignans and polyphenols, lipotropes and methyl donors, such as choline, methionine, betaine, inositol and folate and antinutrients; these are defined as compounds that interfere with the absorption of nutrients such as phytic acid, tannins and saponins endowed with antioxidant and anti-carcinogenic effects (Fardet, 2010; Jones and Engleson, 2010; Jonnalagadda et al., 2011; Slavin et al., 2001). Cereal grain is mainly used (~90%) in animal feeding and its nutritional composition ranges from 21% to 27% of total dietary fiber, 12%–16% of crude protein and

18%–22% of crude fat (Kahlon, 2009). Corn is another valuable fiber source since it possesses no detrimental effects on palatability and nutrient digestibility, also lowering the glycemic response in adult dogs (de Godoy et al., 2009). Although corn fiber contains phenolic compounds with known antioxidant, anti-mutagenic and cholesterol-lowering effects (Wilson et al., 2000) that can reduce the incidence of colon cancer in humans (Lamy et al., 2014), these effects have not been investigated in dogs and cats. Therefore, further studies are warranted. Rice bran is an excellent source of essential amino acids since it is particularly rich in sulfur-containing amino acids, micronutrients such as magnesium, manganese and B vitamins (Ryan, 2011), bioactive molecules such as tocopherols, tocotrienols, polyphenols like ferulic acid and α-lipoic acid, phytoesterols, γ-oryzanol and carotenoids such as carotene, lycopene, lutein and zeaxanthin, all of which have strong antioxidant, anti-inflammatory and chemopreventive properties in management and prevention of chronic diseases such as cardiovascular disease, type-2 diabetes, and obesity (Ryan, 2011). In addition, rice bran oil contains a good fatty acid profile including mostly mono- and poly-unsaturated fatty acids [oleic acid (38.4%), linoleic acid (34.4%) and α-linolenic acid (2.2%)] and about 1.5% γ-oryzanol, all of which have a strong antioxidant capacity, as observed in rodents, rabbits, non-human primates and humans (Cicero and Derosa, 2005). During pet food heat processing, the Maillard reaction, i.e. a non-enzymatic browning and flavoring reaction (van Rooijen et al., 2013), reduces the bioavailability of essential amino acids such as lysine (Friedman, 1996). Therefore, pet food can supply less lysine than the animal may require thus needing the addition of a dietary supplement to integrate such deficiency. Understanding the nutritional benefits of functional foods currently available is of key importance to provide dogs and cats with the correct diet to keep them healthy. For this reason, softwares are available online to allow the consumer to choose the appropriate pet food based on the desired ingredients and diet (BlueBuffalo; Purinaone; Forza10usa).

2. Aim and searching criteria

The aim of this review is to discuss the availability and use of functional foods in dogs and cats. We searched Pubmed/Medline using the keywords "dogs", "cats", "functional", "food", "nutraceutical" and "diet" alone or combined. Selected papers from 1941 to 2017 were chosen based on their content.

3. Functional foods and dog nutrition

Several studies focused on the role of functional foods in dog nutrition (Adolphe et al., 2012; Cortese et al., 2015; Destefanis et al., 2016; Di Cerbo et al., 2016; Di Cerbo et al., 2014; Di Cerbo et al., 2015b; Di Cerbo et al., 2017; Fahnestock et al., 2012; Pasquini et al., 2013; Ponzio et al., 2013; Sechi et al., 2015; Sechi et al., 2017; Spears et al., 2004; Swanson et al., 2002; Tidu et al., 2013) are summarized in Table 1. For instance, in adult male beagles, oligofructose-enriched diet decreased fecal ammonia and *Clostridium perfringens* concentrations, while total aerobes increased, thus ameliorating the overall dog health (Flickinger et al., 2003). Fructooligosaccharides (FOS), were used alone or in combination with mannan-oligosaccharide in dogs fed on a meat-based diet (Swanson et al., 2002). Dogs showed greater ileal immunoglobulin A concentration, whereas they displayed lower fecal total indole and phenol concentrations, if compared with untreated controls. A further study tested a 6-month maintenance diet (FOS as well as corn, fish meal, processed proteins of chicken, poultry fat, beet pulp, yeast, fish oil, minerals, dried yeast (Bio mannan-oligosaccharides), *Yucca schidigera*, Vitamin A, D3 and E, choline chloride, copper chelate of amino acids hydrate, DL-methionine, taurine, L-carnitine and tocopherols, *Grifola frondosa*, *Curcuma longa*, *Carica papaya*, *Punica granatum*, *Aloe vera*, *Polygonum L.*, *Haematococcus pluvialis*, *Solanum licopersicum*, and *Vitis vinifera*) on oxidative stress markers in 12 adult dogs (Pasquini et al., 2013). These dogs presented oxidative imbalance in the form of increased derivatives of reactive oxygen metabolites (d-ROMs) and reduced biological antioxidant potential (BAP; a spectrophotometric test that evaluates blood plasma antioxidant potential by measuring its ferric reducing ability) and retinol. At 6 months, a significant reduction in d-ROMs, primarily hydroperoxides and platelets, as well as an increase in both retinol and BAP was observed, suggesting a restored oxidative balance. This evidence supports the idea that an adequate diet may be crucial to achieve a good oxidative balance in dogs. Conversely, oxidative imbalance may occur after consuming a high glycemic index meal (Adolphe et al., 2012). In order to test this hypothesis, the authors compared postprandial responses of 4 complex carbohydrate sources (barley, corn, peas and rice) vs. a simple carbohydrate (glucose) in 6 dogs reporting that peas had the lowest glycemic index value (29%) compared to barley and rice (51 and 55%, respectively) and could be considered as part of a balanced diet. A further study by Ponzio et al. (2013) evaluated the effects of a specific diet (hydrolyzed fish protein, hydrolyzed potato protein, dried yeast, FOS, vitamin E, ascorbic acid, vitamin B12, niacin, vitamin A, calcium pantothenate, riboflavin, pyridoxine hydrochloride, thiamine mononitrate, folic acid, choline chloride, DL-methionine, L-carnitine, *Yucca schidigera* extract, beta-carotene, *Lepidium meyenii*, and *Tribulus terrestris*) on reproduction in 14 fertile male dogs, divided in 4 age groups (1–2 years, 3–4 years, 5–7 years, and 8–10 years), over a 4-month period, which was preceded by a 3 months pre-treatment period with their usual diet (Ponzio et al., 2013). A constant improvement in metabolic activity (free thyroxine and testosterone) was observed within 45 days since the beginning of the diet enriched with antioxidants with a consequent positive effect on fertility and thyroid activity. Qualitative analysis of semen showed a significant increase in motility and vitality in dogs aged between 2 and 7. These results suggest that a diet enriched with antioxidants can be used to achieve a better reproductive performance. The canine model has been used to investigate the relationship among cognitive impairment in aging, brain-derived neurotrophic factor (BDNF) and diet, but also among behavioral disturbances, neuroendocrine parameters modification and diet (Behavioral, SANYpet S.p.A., Padua, Italy) (Di Cerbo et al., 2017; Fahnestock et al., 2012; Sechi et al., 2015; Sechi et al., 2017). These studies showed that dogs receiving two different antioxidant- and botanical-enriched diets (rice, fish meal, vegetable fats and oils, fish oil, beet pulp, minerals, dehydrated yeast, FOS, *Yucca schidigera*, *Grifola frondosa*, *Curcuma longa*, *Carica papaya*, *Punica granatum*, *Aloe vera*, *Polygonum cuspidatum*, *Haematococcus pluvialis*, *Solanum lycopersicum*, *Vitis vinifera*, *and Rosmarinus officinalis*) presented significantly higher BDNF (Sechi et al., 2015), lower d-ROMs and normalized neuroendocrine parameter levels as well as an overall improvement in behavioral disturbances and their related clinical signs (rice flour, fish protein hydrolysate, potato protein hydrolysate, minerals, *Punica granatum*, *Valeriana officinalis*, *Rosmarinus officinalis*, *Tilia spp.*, *Crataegus oxyacantha L.* tea extract, and L-tryptophan), if compared to animal fed on a control diet (Di Cerbo et al., 2017; Sechi et al., 2017). This evidence suggests that dietary intervention might be a valuable alternative for treatment of cognitive deficits and behavioral disturbances in dogs.

Halitosis is a condition affecting both dogs and humans impacting their relationships (Di Cerbo et al., 2015b). A randomized placebo-controlled cross-over clinical evaluation assessed the effectiveness of a dedicated diet (Forza10 OralActive, SANYpet S.p.A., Padua, Italy) in improving chronic halitosis in 16 dogs of different breeds and ages (Di Cerbo et al., 2015b). Briefly, it was possible to evaluate the efficacy of the diet (rice, fish meal, vegetable fats and oils, fish oil, beet pulp, minerals, dehydrated yeast, FOS, *Yucca schidigera*, propolis, *Salvia officinalis*, lysozyme, bioflavonoids, *Thymus vulgaris*, and *Ribes nigrum*) on oral volatile sulfur compounds, e.g. methyl mercaptan, hydrogen sulfide and dimethyl sulfide, using gas chromatography, which evaluated the concentration of the aforementioned compounds over 30 days. A significant decrease in halitosis-related sulfur compounds was observed. Moreover, such improvement was still evident at 20 days post interruption of the diet supporting the long-lasting efficacy of the compound. Di Cerbo and coworkers observed a pivotal role of a functional diet (hydrolyzed proteins of fish and vegetable origin, minerals, used as glidants, *Melaleuca alternifolia*, *Tilia platyphyllos scapoli et cordata*, *Allium sativum L.*, *Rosa canina L.*, and zinc) in relieving chronic otitis externa-associated symptoms limiting the need of pharmacological therapy to treat this condition (Di Cerbo et al., 2016). In this study, 15 adult dogs of different breeds and ages, affected by chronic otitis externa, received a functional diet along with pharmacological therapy (OTOMAX, 8 drops a day for 7 days). The nutraceutical diet, endowed with anti-inflammatory and antioxidant activities, significantly decreased the mean score intensity of all symptoms (occlusion of ear canal, erythema, discharge quantity, and odor) after 90 days of intervention. In this evaluation, dogs received the pharmacological treatment for the first 8 days of diet supplementation, while they received diet alone for the remaining 82 days. This result is of significant relevance in light of the growing of antimicrobial resistance to pharmacological therapy and represents a starting point for developing functional foods endowed with antibacterial activity. A further study investigated the effect of an immune-modulating diet (IMMD) or standard diet (SD) combined with anti-Leishmania pharmacological therapy (meglumine antimoniate and allopurinol), in 2 groups of 20 dogs (IMMD and SD groups) of different breeds and ages, affected by canine Leishmaniasis (CL), at 0, 3, 6 and 12 months (Cortese et al., 2015). The IMMD restored the levels of regulatory T cells that are reduced during CL, if compared to dogs receiving the SD, at 3, 6 and 12 months. At 6 and 12 months, dogs fed on the IMMD also showed a decrease in T helper cells comparable to the levels observed in healthy dogs. This evidence suggests that a specific diet can regulate the immune response in dogs affected by CL during pharmacological treatment. The same immune-modulating diet resulted particularly effective in reducing the overall mean intensity of tear production, conjunctival inflammation, corneal keratinization, corneal pigment density and mucus discharge which are the most common symptoms of canine keratoconjunctivitis sicca (Destefanis et al., 2016).

Pet food palatability has also been object of study since this feature is of key importance in terms of suitability and safety. Spears et al. (2004) examined palatability of a dry canine diet and its effect on digestion of stabilized rice bran by determining fecal characteristics, food intake, selected immune mediators and blood lipid characteristics (Spears et al., 2004). In the first experiment, the authors compared the palatability of 4 diets containing poultry fat (Test diet 1) or soybean oil (Test diet 2) combined with either 12% stabilized (Test diet 3) or defatted rice bran (Test diet 4) which were fed on 20 dogs for 4 days. Food intake improved in dogs fed on Test diet 1 combined with 12% stabilized rice bran. In the second experiment, 36 beagles received 6 diets containing 12% stabilized or defatted rice bran diet combined with poultry fat, beef tallow, or poultry fat:soybean oil (50:50). Dogs on a defatted rice bran diet showed significantly lower plasma phospholipid total monounsaturated fatty acids with respect to those on a stabilized rice bran diet. They observed that stabilized rice bran was well tolerated in dogs with no detrimental effect on nutrient digestibility and fecal characteristics and without promoting changes in inflammatory and immune responses. Moreover, stabilized rice bran diet presented better palatability compared to the defatted rice bran diet.

4. Functional foods and cat nutrition

Compared to dogs, cats are carnivorous animals with different nutritional needs (Legrand-Defretin, 1994). Thus, specific functional foods have been investigated in cat nutrition, as summarized in Table 2. In a randomized, double-blind, controlled clinical trial involving 55 cats with chronic diarrhea, the efficacy of either a high (10%) or low fat (23%) highly digestible diet (soy flakes, soy protein isolate, turkey and turkey by-product meal, corn starch, oat meal, oat fiber, beef tallow, vitamins and minerals) was evaluated by assessing the fecal score (FSa). All cats responded to the diets tested with an increase in FSa within the first week, achieving a maximum response to diet supplementation within 3 weeks. Furthermore, one third of the cats developed normal stools. No significant differences were observed in response to both diets, indicating that dietary fat amount is not a key factor in dietary management of cats with diarrhea (Laflamme et al., 2011).

In a further study, inclusion of 26% full-fat rice bran in a purified cat diet led to a significantly lower mean whole blood taurine concentration, if compared with controls fed on a purified diet containing 26% corn starch (Stratton-Phelps et al., 2002). The lower taurine concentration observed in cats fed on the rice bran diet was due to increased fecal excretion of conjugated bile acids in addition to changes in hindgut microbiota due to the indigestible protein fraction of rice bran able to degrade taurine (this amino acid is not degraded under physiological conditions). Based on this outcome, a higher concentration of dietary taurine ($>$ 0.05%) should be included in feline diets that contain rice bran. Cats can self regulate food selection and intake to balance macronutrient intake regardless of differences in moisture content and textural properties of commercial cat diets (Hewson-Hughes et al., 2013).

Even under artificial selection (domestication), where humans largely determine the diet of the animal, evidence suggests that, when provided with a choice of foods with different nutritional profiles, cats consume different quantities of different foods to balance their nutrient intake. This was shown by Hewson-Hughes and co-authors (Hewson-Hughes et al., 2013) by feeding 45 cats on 2 different commercial diets (wet diet: Sheba® chunks in jelly, Turkey and Chicken variety, Wd; dry diets: (Whiskas® TOP, Chicken variety, Dd) in different combinations (1 wet + 3 dry; 1 dry + 3 wet; 3 wet + 3 dry). Diets were offered simultaneously and separated by a phase in which diets were offered sequentially in 3-day cycles. This study shows a convergence upon the same dietary macronutrient composition within each experiment as well as over the course of the 3-day cycles. Moreover, despite differences in dietary options, the macronutrient composition of the diets was remarkably similar across all experiments. Besides composition, acceptance and digestibility of nutrients are other key factors that need to be taken into account in cat nutrition. Since apple pomace has a low digestibility (Fekete et al., 2001), it was mixed with a meat-based diet at an inclusion level of 10, 20, and 40% and fed to 9 adult neutered European shorthaired obese cats (Fekete et al., 2001). Inclusion of apple pomace (10 or 20% of the diet) did not decrease food palatability, reduced the energy density, slightly changed the digestibility of fat, and considerably decreased the digestibility of crude protein. Energy density decreased proportionally to the percentage of apple pomace added to the diet. Unfortunately, at a 40% inclusion rate, a lower food intake was observed. Therefore, inclusion of palatable fibrous components at a restricted inclusion rate in the diet of obese cats represents a good way to reduce food energy content and maintain a physiological level of food intake.

5. The pet food market

Adequacy and safety of food supply are of great interest to consumers (Buchanan et al., 2011). Generally, pet owners do not refuse to provide foods that can support health and wellness of their animals, but at the same time, doubt their safety. For instance, incorporation of corn and wheat that have documented antioxidant and anticancer activity (Wood et al., 1994) into pet foods has been perceived as negative by a subgroup of pet owners who believe that they are of lower quality or of poor nutritional value for dogs and cats, despite them matching the Association of American Feed Control Officials (AAFCO) standards (Carter et al., 2014). Pet owners have shown increased interest in holistic, natural diets containing wholesome ingredients, such as oats (*Avena sativa*) and barley (*Hordeum vulgare*), which can

Table 2
Studies of functional foods and functional food-containing diets in cats.

Functional food/diet containing functional foods	Health benefits	References
Apple pomace (10 and 20% apple pomace diet)	↓energy density ↓digestibility of crude protein	Fekete et al., 2001
Full-fat stabilized rice bran (260 g/kg) with 12.1% dry matter acid detergent fiber and 31.3% dry matter neutral detergent fiber, casein (180 g/kg), lactalbumin 180 (g/kg), chicken fat (310.5 g/kg), taurine (3 g/kg), vitamin mixture (10 g/kg), L-methionine (3 g/kg), L-arginine (3 g/kg), and mineral mixture (50 g/kg).	↓taurine levels in bloodstream ↑fecal excretion of conjugated bile acids	Stratton-Phelps et al., 2002
High-fat (45% calories from fat) or low-fat diet (23.8% calories from fat), soy flakes and soy protein isolate, turkey and turkey by-product meal, corn starch, oat meal, oat fiber, beef tallow, vitamins and minerals	↑fecal score and normal stools development	Laflamme et al., 2011

reduce the risk of obesity (Jones and Engleson, 2010) and prevent diabetes mellitus (the greater the intake of whole grains is, the lower the fasting insulin levels are likely to be) (Pereira et al., 2002). Besides food nutrition-related benefits, safety issues should also be taken into account. In recent years, pet food safety has represented a substantial challenge because of the direct impact of food contaminations on both animals and humans (FDA, 2005). Such contaminations could also lead to nutritional deficiencies despite a correct diet formulation. However, the effect of contaminations (caused, for instance, by microorganisms) of pet foods on animal health has not been extensively investigated due to the multitude of possible sources of contamination (LeJeune and Hancock, 2001). Moreover, most commonly used pet foods in the UK employ products of unknown animal origin including bovine, porcine and chicken DNA in various proportions and combinations often not explicitly indicated on the product labels (Maine et al., 2015). Therefore, the pet food industry still has various challenges to overcome in order to provide better nutriments to dogs and cats.

6. Conclusions

Due to a reduction in the number of family components in industrialized countries, the role of pets such as dogs and cats as ‘family members’ has gained increasing importance (Shepherd, 2008), and their health and well-being have become a prominent challenge for their owners (Buchanan et al., 2011). As a matter of fact, companion animals, most commonly dogs and cats, provide a positive impact on humans' emotional (Allen et al., 1991; Serpell, 1991) and physical health (Friedmann and Thomas, 1995; Headey, 1999). Due to the difficulty understanding pet food labels, consumers' education becomes a key issue for the marketing of functional foods. In addition, research on pet food is still scarce. Accurate claims on food labels help consumers select products that satisfy their desire to promote animal care and improve their pets' health. Food scientists and healthcare professionals should therefore work together to improve consumers' education by accurately characterizing new scientific developments or achievements in nutrition. The ultimate success of functional pet foods will depend on delivering bioactive components in a predictable, safe and functional manner to effectively reduce the risk of disease and support the domestic animal's body. Future basic and applied nutritional research should further explore the role and mechanism of functional foods in dogs and cats.

Competing interests

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References

Adolphe, J.L., Drew, M.D., Huang, Q., Silver, T.I., Weber, L.P., 2012. Postprandial impairment of flow-mediated dilation and elevated methylglyoxal after simple but not complex carbohydrate consumption in dogs. Nutr. Res. 32, 278–284 (New York, N.Y.).
Allen, K.M., Blascovich, J., Tomaka, J., Kelsey, R.M., 1991. Presence of human friends and pet dogs as moderators of autonomic responses to stress in women. J. Pers. Soc. Psychol. 61, 582–589.
Axelsson, E., Ratnakumar, A., Arendt, M.L., Maqbool, K., Webster, M.T., Perloski, M., Liberg, O., Arnemo, J.M., Hedhammar, A., Lindblad-Toh, K., 2013. The genomic signature of dog domestication reveals adaptation to a starch-rich diet. Nature 495, 360–364.
Blaiotta, G., Murru, N., Di Cerbo, A., Succi, M., Coppola, R., Aponte, M., 2016. Commercially standardized process for probiotic “Italico” cheese production. Food Sci. Technol. 79, 601–608.
BlueBuffalo. http://bluebuffalo.com/true-blue-test/compare-dog-food/.
Borneo, R., Leon, A.E., 2012. Whole grain cereals: functional components and health benefits. Food Funct. 3, 110–119.
Bosch, G., Hagen-Plantinga, E.A., Hendriks, W.H., 2015. Dietary nutrient profiles of wild wolves: insights for optimal dog nutrition? Br. J. Nutr. 113 (Suppl), S40–S54.
Brennan, S.C., Cleary, L.J., 2005. The potential use of cereal (1 → 3,1 → 4)-β-d-glucans as functional food ingredients. J. Cereal Sci. 42, 1–13.
Brugger, A., Lariviere, L.A., Mumme, D.L., Bushnell, E.W., 2007. Doing the right thing: infants' selection of actions to imitate from observed event sequences. Child Dev. 78, 806–824.
Buchanan, R.L., Baker, R.C., Charlton, A.J., Riviere, J.E., Standaert, R., 2011. Pet food safety: a shared concern. Br. J. Nutr. 106 (Suppl. 1), S78–S84.
Carter, R.A., Bauer, J.E., Kersey, J.H., Buff, P.R., 2014. Awareness and evaluation of natural pet food products in the United States. J. Am. Vet. Med. Assoc. 245, 1241–1248.
Cicero, A.F.G., Derosa, G., 2005. Rice bran and its main components: potential role in the management of coronary risk factors. Curr. Top. Nutraceutical Res. 3, 29–46.
Cook, A., Arter, J., Jacobs, L.F., 2014. My owner, right or wrong: the effect of familiarity on the domestic dog's behavior in a food-choice task. Anim. Cogn. 17, 461–470.
Corbo, M.R., Bevilacqua, A., Petruzzi, L., Casanova, F.P., Sinigaglia, M., 2014. Functional beverages: the emerging side of functional foods. Compr. Rev. Food Sci. Food Saf. 13, 1192–1206.
Cortese, L., Annunziatella, M., Palatucci, A.T., Lanzilli, S., Rubino, V., Di Cerbo, A., Centenaro, S., Guidetti, G., Canello, S., Terrazzano, G., 2015. An immune-modulating diet increases the regulatory T cells and reduces T helper 1 inflammatory response in Leishmaniosis affected dogs treated with standard therapy. BMC Vet. Res. 11, 295.
Delzenne, N.M., Kok, N., 2001. Effects of fructans-type prebiotics on lipid metabolism. Am. J. Clin. Nutr. 73, 456S–458S.
Destefanis, S., Giretto, D., Muscolo, M.C., Di Cerbo, A., Guidetti, G., Canello, S., Giovazzino, A., Centenaro, S., Terrazzano, G., 2016. Clinical evaluation of a nutraceutical diet as an adjuvant to pharmacological treatment in dogs affected by Keratoconjunctivitis sicca. BMC Vet. Res. 12, 214.
Di Cerbo, A., Palmieri, B., 2015. Review: the market of probiotics. Pak. J. Pharm. Sci. 28, 2199–2206.
Di Cerbo, A., Pezzuto, F., Palmieri, L., Palmieri, B., 2012. The use of probiotics in the end-stage renal disease management. Minerva Biotec. 24, 155–170.
Di Cerbo, A., Pezzuto, F., Palmieri, L., Rottigni, V., Iannitti, T., Palmieri, B., 2013. Clinical and experimental use of probiotic formulations for management of end-stage renal disease: an update. Int. Urol. Nephrol. 45, 1569–1576.
Di Cerbo, A., Palmieri, B., Chiavolelli, F., Guidetti, G., Canello, S., 2014. Functional foods in pets and humans. Int. J. Appl. Res. Vet. Med. 12, 192–199.
Di Cerbo, A., Laurino, C., Palmieri, B., Iannitti, T., 2015a. A dietary supplement improves facial photoaging and skin sebum, hydration and tonicity modulating serum fibronectin, neutrophil elastase 2, hyaluronic acid and carbonylated proteins. J. Photochem. Photobiol. B 144, 94–103.
Di Cerbo, A., Pezzuto, F., Canello, S., Guidetti, G., Palmieri, B., 2015b. Therapeutic effectiveness of a dietary supplement for management of halitosis in dogs. J. Vis. Exp. 101, e52717.
Di Cerbo, A., Centenaro, S., Beribe, F., Laus, F., Cerquetella, M., Spaterna, A., Guidetti, G., Canello, S., Terrazzano, G., 2016. Clinical evaluation of an antiinflammatory and antioxidant diet effect in 30 dogs affected by chronic otitis externa: preliminary results. Vet. Res. Commun. 40, 29–38.
Di Cerbo, A., Sechi, S., Canello, S., Guidetti, G., Fiore, F., Cocco, R., 2017. Behavioral

disturbances: an innovative approach to monitor the modulatory effects of a nutraceutical diet. J. Vis. Exp. 119.
Fahnestock, M., Marchese, M., Head, E., Pop, V., Michalski, B., Milgram, W.N., Cotman, C.W., 2012. BDNF increases with behavioral enrichment and an antioxidant diet in the aged dog. Neurobiol. Aging 33, 546–554.
Fardet, A., 2010. New hypotheses for the health-protective mechanisms of whole-grain cereals: what is beyond fibre? Nutr. Res. Rev. 23, 65–134.
FDA, 2005. Diamond pet food recalled due to aflatoxin. In: Recall. Firm Press Release Accessed december 19, Available from: www.fda.gov/Safety/Recalls/ArchiveRecalls/2005>.
Fekete, S., Hullar, I., Andrasofszky, E., Rigo, Z., Berkenyi, T., 2001. Reduction of the energy density of cat foods by increasing their fibre content with a view to nutrients' digestibility. J. Anim. Physiol. Anim. Nutr. 85, 200–204.
Flickinger, E.A., Schreijen, E.M., Patil, A.R., Hussein, H.S., Grieshop, C.M., Merchen, N.R., Fahey Jr., G.C., 2003. Nutrient digestibilities, microbial populations, and protein catabolites as affected by fructan supplementation of dog diets. J. Anim. Sci. 81, 2008–2018.
Forza10usa. http://www.forza10usa.com/compare-your-pet-food/.
Friedman, M., 1996. Food browning and its prevention: an overview. J. Agric. Food Chem. 44, 631–653.
Friedmann, E., Thomas, S.A., 1995. Pet ownership, social support, and one-year survival after acute myocardial infarction in the Cardiac Arrhythmia Suppression Trial (CAST). Am. J. Cardiol. 76, 1213–1217.
de Godoy, M.R., Bauer, L.L., Parsons, C.M., Fahey Jr., G.C., 2009. Select corn coproducts from the ethanol industry and their potential as ingredients in pet foods. J. Anim. Sci. 87, 189–199.
Grzeskowiak, L., Endo, A., Beasley, S., Salminen, S., 2015. Microbiota and probiotics in canine and feline welfare. Anaerobe 34, 14–23.
Guidetti, G., Di Cerbo, A., Giovazzino, A., Rubino, V., Palatucci, A.T., Centenaro, S., Fraccaroli, E., Cortese, L., Bonomo, M.G., Ruggiero, G., Canello, S., Terrazzano, G., 2016. In vitro effects of some botanicals with anti-inflammatory and antitoxic activity. J. Immunol. Res. 2016, 5457010.
Hasler, C.M., 2000. The changing face of functional foods. J. Am. Coll. Nutr. 19, 499S–506S.
Headey, B., 1999. Health benefits and health cost savings due to pets: preliminary estimates from an Australian National Survey. Soc. Indic. Res. 47, 233–243.
Hewson-Hughes, A.K., Hewson-Hughes, V.L., Colyer, A., Miller, A.T., Hall, S.R., Raubenheimer, D., Simpson, S.J., 2013. Consistent proportional macronutrient intake selected by adult domestic cats (*Felis catus*) despite variations in macronutrient and moisture content of foods offered. J. Comp. Physiol. B Biochem. Syst. Environ. Physiol. 183, 525–536.
Hussein, H.S., Flickinger, E.A., Fahey Jr., G.C., 1999. Petfood applications of inulin and oligofructose. J. Nutr. 129, 1454S–1456S.
Iannitti, T., Palmieri, B., 2010. Therapeutical use of probiotic formulations in clinical practice. Clin. Nutr. 29, 701–725.
Jenkins, A.L., Jenkins, D.J., Wolever, T.M., Rogovik, A.L., Jovanovski, E., Bozikov, V., Rahelic, D., Vuksan, V., 2008. Comparable postprandial glucose reductions with viscous fiber blend enriched biscuits in healthy subjects and patients with diabetes mellitus: acute randomized controlled clinical trial. Croat. Med. J. 49, 772–782.
Jones, J.M., Engleson, J., 2010. Whole grains: benefits and challenges. Annu. Rev. Food Sci. Technol. 1, 19–40.
Jonnalagadda, S.S., Harnack, L., Liu, R.H., McKeown, N., Seal, C., Liu, S., Fahey, G.C., 2011. Putting the whole grain puzzle together: health benefits associated with whole grains—summary of American Society for Nutrition 2010 Satellite Symposium. J. Nutr. 141, 1011S–1022S.
Kahlon, T.S., 2009. Rice bran: production, composition, functionality and food applications, physiological benefits. In: Boca Raton, U. (Ed.), Fiber Ingredients: Food Applications and Health Benefits. F Taylor & Francis Group, pp. 305–322 (Cho, S. S. Samuel, P.).
Laflamme, D.P., Xu, H., Long, G.M., 2011. Effect of diets differing in fat content on chronic diarrhea in cats. J. Vet. Intern. Med./Am. Coll. Vet. Intern. Med. 25, 230–235.
Lamy, S., Ouanouki, A., Beliveau, R., Desrosiers, R.R., 2014. Olive oil compounds inhibit vascular endothelial growth factor receptor-2 phosphorylation. Exp. Cell Res. 322, 89–98.
Legrand-Defretin, V., 1994. Differences between cats and dogs: a nutritional view. Proc. Nutr. Soc. 53, 15–24.
LeJeune, J.T., Hancock, D.D., 2001. Public health concerns associated with feeding raw meat diets to dogs. J. Am. Vet. Med. Assoc. 219, 1222–1225.
Lyons, D.E., Young, A.G., Keil, F.C., 2007. The hidden structure of overimitation. Proc. Natl. Acad. Sci. U. S. A. 104, 19751–19756.
Maine, I.R., Atterbury, R., Chang, K.C., 2015. Investigation into the animal species contents of popular wet pet foods. Acta Vet. Scand. 57, 7.
Marshall-Pescini, S., Passalacqua, C., Miletto Petrazzini, M.E., Valsecchi, P., Prato-Previde, E., 2012. Do dogs (*Canis lupus familiaris*) make counterproductive choices because they are sensitive to human ostensive cues? PLoS One 7, e35437.
Michel, K.E., 2006. Unconventional diets for dogs and cats. Vet. Clin. North Am. Small Anim. Pract. 36 (1269–1281), vi–vii.
Morris, J.G., 2002. Idiosyncratic nutrient requirements of cats appear to be diet-induced evolutionary adaptations. Nutr. Res. Rev. 15, 153–168.
Morris, P.J., Salt, C., Raila, J., Brenten, T., Kohn, B., Schweigert, F.J., Zentek, J., 2012. Safety evaluation of vitamin A in growing dogs. Br. J. Nutr. 108 (10), 1800–1809.
National Research Council, Division on Earth and Life Studies, Board on Agriculture and Natural Resources, Committee on Animal Nutrition, Subcommittee on Dog and Cat Nutrition, 2006. Nutrient Requirements of Dogs and Cats. National Academies Press.
Pasquini, A., Roberti, S., Meucci, V., Luchetti, E., Canello, S., Guidetti, G., Biagi, G., 2013. Association between body condition and oxidative status in dogs. Food Nutr. Sci. 4, 191–196.
Pereira, M.A., Jacobs Jr., D.R., Pins, J.J., Raatz, S.K., Gross, M.D., Slavin, J.L., Seaquist, E.R., 2002. Effect of whole grains on insulin sensitivity in overweight hyperinsulinemic adults. Am. J. Clin. Nutr. 75, 848–855.
Plantinga, E.A., Bosch, G., Hendriks, W.H., 2011. Estimation of the dietary nutrient profile of free-roaming feral cats: possible implications for nutrition of domestic cats. Br. J. Nutr. 106 (Suppl. 1), S35–S48.
Ponzio, P.C., Canello, S., Guidetti, G., Sferra, C., Macchi, E., 2013. Correlation between reproductive efficiency (semen quality and endocrine function) and dietary supplementation in dog breeding. Veterinaria 27, 15–22.
Purinaone. https://www.purinaone.com/dogs/why-switch/compare-your-pet-food.
Rebello, C.J., Liu, A.G., Greenway, F.L., Dhurandhar, N.V., 2013. Dietary strategies to increase satiety. Adv. Food Nutr. Res. 69, 105–182.
Reimer, R.A., Maurer, A.D., Eller, L.K., Hallam, M.C., Shaykhutdinov, R., Vogel, H.J., Weljie, A.M., 2012. Satiety hormone and metabolomic response to an intermittent high energy diet differs in rats consuming long-term diets high in protein or prebiotic fiber. J. Proteome Res. 11, 4065–4074.
Ricciardi, A., Blaiotta, G., Di Cerbo, A., Succi, M., Aponte, M., 2014. Behaviour of lactic acid bacteria populations in Pecorino di Carmasciano cheese samples submitted to environmental conditions prevailing in the gastrointestinal tract: evaluation by means of a polyphasic approach. Int. J. Food Microbiol. 179, 64–71.
Romano, A., Blaiotta, G., Di Cerbo, A., Coppola, R., Masi, P., Aponte, M., 2014. Spray-dried chestnut extract containing *Lactobacillus rhamnosus* cells as novel ingredient for a probiotic chestnut mousse. J. Appl. Microbiol. 116, 1632–1641.
van Rooijen, C., Bosch, G., van der Poel, A.F., Wierenga, P.A., Alexander, L., Hendriks, W.H., 2013. The Maillard reaction and pet food processing: effects on nutritive value and pet health. Nutr. Res. Rev. 26, 130–148.
Ryan, E.P., 2011. Bioactive food components and health properties of rice bran. J. Am. Vet. Med. Assoc. 238, 593–600.
Sechi, S., Chiavolelli, F., Spissu, N., Di Cerbo, A., Canello, S., Guidetti, G., Fiore, F., Cocco, R., 2015. An antioxidant dietary supplement improves brain-derived neurotrophic factor levels in serum of aged dogs: preliminary results. J. Vet. Med. 2015, 412501.
Sechi, S., Di Cerbo, A., Canello, S., Guidetti, G., Chiavolelli, F., Fiore, F., Cocco, R., 2017. Effects in dogs with behavioural disorders of a commercial nutraceutical diet on stress and neuroendocrine parameters. Vet. Rec. 180, 18.
Serpell, J., 1991. Beneficial effects of pet ownership on some aspects of human health and behaviour. J. R. Soc. Med. 84, 717–720.
Shepherd, A.J., 2008. Results of the 2006 AVMA survey of companion animal ownership in US pet-owning households. J. Am. Vet. Med. Assoc. 232, 695–696.
Shiby, V.K., Mishra, H.N., 2013. Fermented milks and milk products as functional foods—a review. Crit. Rev. Food Sci. Nutr. 53, 482–496.
Slavin, J.L., Lloyd, B., 2012. Health benefits of fruits and vegetables. Adv. Nutr. 3, 506–516.
Slavin, J.L., Jacobs, D., Marquart, L., Wiemer, K., 2001. The role of whole grains in disease prevention. J. Am. Diet. Assoc. 101, 780–785.
Spears, J.K., Grieshop, C.M., Fahey Jr., G.C., 2004. Evaluation of stabilized rice bran as an ingredient in dry extruded dog diets. J. Anim. Sci. 82, 1122–1135.
Stratton-Phelps, M., Backus, R.C., Rogers, Q.R., Fascetti, A.J., 2002. Dietary rice bran decreases plasma and whole-blood taurine in cats. J. Nutr. 132, 1745S–1747S.
Swanson, K.S., Grieshop, C.M., Flickinger, E.A., Bauer, L.L., Healy, H.P., Dawson, K.A., Merchen, N.R., Fahey Jr., G.C., 2002. Supplemental fructooligosaccharides and mannanoligosaccharides influence immune function, ileal and total tract nutrient digestibilities, microbial populations and concentrations of protein catabolites in the large bowel of dogs. J. Nutr. 132, 980–989.
Swanson, K.S., Schook, L.B., Fahey Jr., G.C., 2003. Nutritional genomics: implications for companion animals. J. Nutr. 133, 3033–3040.
Tidu, L., Bacciu, N., Rucco, G., Nardi, S., Santoro, M., Renaville, B., 2013. Plasma fatty acid profiles during the first year in dogs with and without hip dysplasia: preliminary results. Trends Vet. Sci. 35–39.
Topal, J., Gergely, G., Miklosi, A., Erdohegyi, A., Csibra, G., 2008. Infants' perseverative search errors are induced by pragmatic misinterpretation. Science 321, 1831–1834 (New York, N.Y.).
Tungland, B.C., 2003. Fructooligosaccharides and other fructans: structures and occurrence, production, regulatory aspects, food applications, and nutritional health significance, oligosaccharides in food and agriculture. Am. Chem. Soc. 135–152.
Van Loo, J., Cummings, J., Delzenne, N., Englyst, H., Franck, A., Hopkins, M., Kok, N., Macfarlane, G., Newton, D., Quigley, M., Roberfroid, M., van Vliet, T., van den Heuvel, E., 1999. Functional food properties of non-digestible oligosaccharides: a consensus report from the ENDO project (DGXII AIRII-CT94-1095). Br. J. Nutr. 81, 121–132.
Wenk, C., 2001. The role of dietary fibre in the digestive physiology of the pig. Anim. Feed Sci. Technol. 90, 21–33.
Wilson, T.A., DeSimone, A.P., Romano, C.A., Nicolosi, R.J., 2000. Corn fiber oil lowers plasma cholesterol levels and increases cholesterol excretion greater than corn oil and similar to diets containing soy sterols and soy stanols in hamsters. J. Nutr. Biochem. 11, 443–449.
Wood, P.J., Braaten, J.T., Scott, F.W., Riedel, K.D., Wolynetz, M.S., Collins, M.W., 1994. Effect of dose and modification of viscous properties of oat gum on plasma glucose and insulin following an oral glucose load. Br. J. Nutr. 72, 731–743.
Zicker, S.C., 2008. Evaluating pet foods: how confident are you when you recommend a commercial pet food? Top. Companion Anim. Med. 23, 121–126.