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Meat Technology — Special Issue 64/2

www.meatcon.rs ▪ www.journalmeattechnology.com

UDK: 636.7/.8.045.084.5

ID: 126448393

https://doi.org/10.18485/meattech.2023.64.2.58

Original scientific paper

Evaluation of content and ratio of calcium and phosphorus in commercially available pet food for dogs and cats

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ARTICLE INFO

Keywords:
Pet food
Calcium
Phosphorus

ABSTRACT

Calcium, phosphorus and vitamin D are essential nutrients for dogs and cats, and therefore, they need to be provided in the diet in adequate amounts and in bioavailable forms. Generally, calcium and phosphorus are discussed together because of their close relationship, particularly in bone health. The objective of this study was to determine calcium and phosphorus contents in commercially available pet food for dogs and cats marketed in Serbia, during 2022. The contents of calcium and phosphorus in the examined animal feeds were determined by using standard ISO procedures. According to national and EU regulations, all calcium and phosphorous contents were in permitted content ranges. The quality and safety of pet food are of great importance to pet health and welfare over their prolonged lives. These results could be discussed from a nutritional, ecological and economic point of view in order to meet optimal formulation of diets.

1. Introduction

Calcium, phosphorus and vitamin D are essential nutrients for dogs and cats, and therefore, they need to be provided in the diet in adequate amounts and in bioavailable forms. Generally, calcium and phosphorus are discussed together because of their close relationship, particularly in bone health. As with calcium, the majority of the body phosphate (approximately 85%) is present in the mineral phase of bone (*Cline*, 2012; *Stockman et al*., 2021). The remainder of body phosphate is present in a variety of inorganic and organic compounds distributed within both intracellular and extracellular compartments. Calcium has many diverse roles in the body including those related to blood clotting, blood pressure, cellular communication, brain function and signal transduction as well as muscle contraction (*Slatopolsky et al.*, 1989). Bone metabolism and calcium and phosphorus absorption and retention are influenced by vitamin D as well as the relative dietary concentrations of these and other minerals. For dogs and cats, vitamin D is also an essential nutrient because its synthesis from sunlight exposure seems to be limited (*Morris*,1999: *How et al.*, 1995).

Bioavailability and digestibility of calcium is variable depending on calcium source, physiological status of the animal, and absorption rates in the lumen of the gut. Digestibility of calcium (and phosphorus) is generally low from grain sources. Most grains contain an endogenous mineral binder called phytase, which complexes with phosphorus and calcium as well as other minerals, rendering them poor-

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Paper received May 31st 2023. Paper accepted Jun 18th 2023.
Published by Institute of Meat Hygiene and Technology — Belgrade, Serbia

ly absorbed calcium and phosphorus sources (*Cline*, 2012). Calcium and phosphorus in pet food can be provided by bony raw materials (from meat and fish). Meat sources are typically high in phosphorus but low in calcium, so homemade or raw-type diets must be evaluated closely for calcium and phosphorus content. Many cases of hyperparathyroidism have resulted from a calcium-to-phosphorous imbalance, which can result from feeding high-protein meat products (*Kantorosinski and Morrison*,1988; *Stockman et al.*, 2021; *Baker and Czarnecki-Maulden*, 1991). Conversely, increased calcium absorption can take place when presented with a high ratio of calcium to phosphorus. So, it is vitally important that the correct amount of calcium and phosphorus be supplied in the diet and in the correct ratios (relative proportions) to each other (*Stockman et al.*, 2021). Most commercial pet foods incorporate supplemental calcium into their rations to ensure the correct calcium-to-phosphorous (C/P) ratio is obtained for the targeted life stage and lifestyle. Chronic calcium imbalance had become uncommon in developed countries with the introduction of modern pet foods, but with the resurgence of homemade and raw-type diets for dogs and cats, there is an increased incidence of calcium, phosphorus, and vitamin D imbalance (*Schlesinger and Joffe*, 2011). Nutritional factors suspected to increase the risk of osteochondrosis are rapid growth from *ad libitum* feeding of high-energy foods, high calcium intake and deficiencies in vitamins or trace elements (*Ralphs*, 2005; *Richardson and Zentek*, 1998).

The National Research Council gives recommended allowances for calcium and phosphorus for different life stages of dogs and cats (*NRC*, 2006). It also defines a safe upper limit for calcium of 4.5 g/1000 kcal of metabolizable energy for puppies, specifically those of large and giant breeds, where excess can result in skeletal abnormalities (*Nap and Hazewinkel*, 1994; *Dobenecker et al*., 2006). According to Association of American Feed Control Officials (*AAFCO*, 2022), cats and dogs have specific dietary nutrient requirements, and cats notably having more specialized nutrient needs than dogs. Because of the close relationship of calcium and phosphorus, the Association of American Feed Control Officials (*AAFCO*, 2018) guidelines recommend that commercial dog food not only meets the individual requirements, but also provides a minimum Ca/P ratio of 1:1 and a maximum ratio of 2:1.

Therefore, the objective of this study was to determine calcium and phosphorus contents in commercially available pet food for dogs and cats marketed in Serbia, during 2022. Based on the analysis results, relationship Ca/P was then estimated and discussed.

2. Materials and methods

2.1. Pet food samples

In the present study, 23 samples of commercially available pet food obtained from the Serbian retail market during 2022 were analyzed for calcium and phosphorus contents. These included 13 samples of pet food for dogs and 10 samples of pet food for cats.

2.2. Analytical procedure

The content of calcium in the examined animal feeds was determined according to the standard

ISO procedure (ISO 6449-1, 1985). The titrimetric method is applicable to all animal feeding stuffs having calcium contents greater than 1 g/kg.

The content of phosphorus in the examined animal feeds was determined according to the standard ISO procedure (ISO 6491, 1998). This specifies a spectrometric method for the determination of the phosphorus content of animal feeding stuffs, and this method is applicable to animal feeding stuffs with low phosphorus content (less than 50 g/kg).

2.3. Statistical analysis

Calcium and phosphorus contents in examined samples were determined in duplicate and were presented as mean values with standard deviation (±SD) for cat feed and min and maximum values for dog feed. The results obtained were analyzed using Microsoft Excel software (Windows 11 pro).

3. Results and discussion

Tables 1 and 2 present the calcium and phosphorous contents of the analyzed dog and cat foods compared with the manufacturer's declarations on the labels. In all of the analyzed pet foods, the calcium and phosphorus levels matched the manufacturer's declared values. According to national (*Official Gazette of RS,* No 4/2010, 113/2012, 27/2014, 25/2015, 39/2016, 54/2017) and European Union regulation (*Commission Regulation* No 939/2010), all results were in permitted content ranges, which

were defined in these regulations for the both of analyzed minerals (for calcium ±20% and ±15% of relative value; and for phosphorus: ±0.2% and ±0.15%, respectively, in comparaison with declared values). The determined calcium contents in dog food ranged from the lowest of 0.96% (complete food for medium and large breeds) to 1.57% (complete food for adult dogs) as the maximum value. Regarding the phosphorus content in dog food, the results of the analyses were very similar to the to the producers' declarations on the label, ranging from 0.92 (complete food for medium and large breed puppies) to 1.11% (complete food for medium and large breeds). Calcium and phosphorus contents of the investigated commercial cat foods were the most similar of the two food types to the manufacturer's declarations on the label, and they met the minimum recommended values from *NRC*, (2006), *AAFCO* (2014) and *FEDIAF* (2020). We found that foods marketed for adult cats had a higher calcium content compared to content of this nutrient in feed for dogs, in general. This is attributed to the lack of defined nutritional guidelines for cats (*NRC*, 2006; *AAFCO*, 2022). Some published findings (*Morino et al*., 2014; *Elliot and Barber*, 1998; *Markovich et al*., 2015), indicating that excess phosphorous can cause chronic kidney disease and decreased renal function which is common in geriatric cats, along with our finding raise concern regarding the typical intake of phosphorous and calcium in cats. A change in existing regulatory guidelines with regard to maximum phosphorous in foods formulated for cats should be considered in light of potential safety issues. For both calcium and phosphorous, the analyzed content often exceeded the minimum concentration declared on the food label claim, for both feeds, for cats and dogs.

This study showed that the contents of calcium and phosphorous in dog food are in accordance with the nutritional recommendations for dogs established by National Research Council of Unit-

Table 1. Calcium (%) and phosphorus (%) content in pet food for dogs

Sample	Calcium (%)		Phosphorous (%)		Ca/P ratio
	Declared (min-max)	Determined (min-max)	Declared (min-max)	Determined (min-max)	
Complete food for adult dogs (n=2)	-	1.28–1.57	-	1.07–1.16	1.10–1.46
Complete food for medium and large breed puppies (n=4)	1.20–1.30	1.33–1.45	0.90	0.92–1.04	1.32–1.44
Complete food for medium and large breed puppies and pregnant or lactating dogs (n=2)	1.20–1.25	1.38–1.42	0.90	0.94–1.02	1.35–1.51
Complete food for medium and large breeds. adult dog (n=5)	1.20–1.25	0.96–1.35	0.90	0.96–1.11	0.91–1.33
Total (n=13)	**1.20–1.30**	**0.96–1.57**	**0.90**	**0.92–1.11**	**0.91–1.51**

Table 2. Calcium (%) and phosphorus (%) content in pet food for adult cats

Sample	Calcium (%)				Phosphorous (%)				Ca/P ratio	
	Declared		Determined		Declared		Determined			
	Mean ± Sd	min-max	Mean ± Sd	min-max	Mean ± Sd	min-max	Mean± Sd	min-max	Mean ± Sd	min-max
Complete feed for adult cat (n=10)	1.16 ± 0.90	1.05–1.25	1.45 ± 0.40	1.16–2.38	0.78 ± 0.34	0.0–0.95	1.07±0.11	0.93–1.31	1.33 ± 0.25	1.13–1.98

ed States (*NRC*, 2006), *AAFCO* (2014) and the *FEDIAF* (2020). Our results were similar to FEDIAF (2020) recommendations that the calcium level in a pet food for early growth should be at least 1 g/100 g DM. During late growth, it is recommended that large breed and giant breed puppies continue to be fed a pet food containing at least 1 % calcium until about 6 months of age. During the whole late growth phase, pet foods for puppies of small and medium size breeds can contain less calcium (minimum 0.8 % DM) and the Ca/P ratio can be increased to 1.8/1 (*Lauten et al*. 2002). However, this level has been reported to be marginal for some breeds, particularly during the fast growing phase.

Similar to results for cat food, the results obtained shown that calcium contents (%) (1.45±0.40) as well as the Ca/P ratio (1.33±0.25) were slightly higher compared to results for foods intended for adult maintenance and those for all life stages, for dogs (0.96–1.57% calcium and 0.91–1.51, Ca/P). According to *Greco*, (2008) feeds designed for small, large- and giant-breed puppies have varying amounts of calcium and phosphorus and in appropriate ratios to control growth and development of bones and cartilage, and our results were in accordance with this observation, particularly the calcium content (0.96–1.35% for complete food for medium and large breeds to maximum 1.33–1.45% for medium and large breed puppies and 1.28–1.57%, for adult dogs).

In pet diets, it is necessary to take into account the Ca/P ratio, because it has important consequences for bone development, which can be adversely affected when this ratio increases, resulting in aberrations in bone mineral homeostasis and bone metabolism (*Kumar et al*., 2011). Furthermore, dietary Ca/P ratios are crucial to phytase efficacy and activity (*Angel et al*., 2002). Thus, most commercial pet foods incorporate supplemental calcium into their rations to ensure the correct Ca/P ratio is obtained for the targeted life stage and lifestyle. In this study, Ca/P ratio ranged from 0.91 to 1.1 in dog food, while in cat food, it was slightly higher, ranging from 1.13 to 1.98. Also, our general Ca/P ratio (1.33±0.25) for pet food for adult cats was similar to those reported in study by *Summers et al*. (2020) in cat foods labeled for senior and adult cats (1.3 and 0.8–1.7, respectively). The Ca/P ratios in pet food for dogs (0.91–1.51) were in accordance, in general, with the recommended (*AAFCO*, 2018) guidelines, in which a minimum Ca/P ratio of 1:1 and a maximum ratio of 2:1 are advised. Only in complete foods for medium and large breeds was a slightly lower Ca/P ratio (0.91) obtained compared to the recommended minimum value (1:1).

Our study had several limitations. The sample population represented the products within the Serbian market that are available for the local cat and dog owners; we could not evaluate the digestibility or bioavailability of dietary nutrients, the source or form of phosphorous, calcium and the content of vitamin D, or evaluate any possible clinical consequences of our findings. We cannot conclude with certainty that any of the tested foods would cause kidney injury to healthy cats, even if fed long term. Additional research into the nutritional requirements of cats and dogs at different life stage is also is required, and it may inform future nutritional guidelines.

5. Conclusion

The quality and safety of pet food are of great importance to pet health and welfare over their prolonged lives. In this study of pet food sold in Serbian markets, the contents of calcium and phosphorous were more or less adequate, and mostly matched the manufacturer's declared values. Despite some deviations from declared values, these variabilities were in the range of permitted tolerances for the compositional labeling of feed materials. Likewise, these results could be discussed from a nutritional, ecological and economic point of view in order to meet optimal formulation of diets.

Disclosure Statement: No potential conflict of interest was reported by authors.

Funding: This study was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, Grant No. 451-03-47/2023-01/200050 from 03.02.2023.

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