Folia biologica (Kraków), vol. **53** (2005), Supplement

Ileal Digestibility of Crude Ash and Minerals in Feeds for the Polar Fox during the Non-mating Period*

Roman SZYMECZKO, Anna PIOTROWSKA and Monika BOGUSŁAWSKA-TRYK

Accepted November 4, 2005

SZYMECZKO R., PIOTROWSKA A., BOGUSŁAWSKA-TRYK M. 2005. Ileal digestibility of crude ash and minerals in feeds for the polar fox during the non-mating period. Folia biol. (Kraków) **53** (Suppl.): 13-17.

The aim of the present research was to compare the content and apparent ileal digestibility of ash and minerals (Ca, P, Mg, Na, K) in feeds used in feeding reproductive polar foxes over the non-mating period on two domestic farms (A and B), differing in reproduction results. The feeds were evaluated based on offal of animal origin and cereals. The greatest differences in the content of nutrients were noted for the concentration of crude ash. Farm A diets demonstrated a few-fold more crude ash content and a greater content of calcium, phosphorus and sodium, as compared with farm B feeds. The digestibility experiments carried out on foxes with 'end to end' ileorectal anastomosis showed a higher (P.05) apparent ileal digestibility of crude ash, calcium, phosphorus, magnesium and potassium in diets B in which the content of ash was three-fold lower than in diets A.

Key words: Ileal digestibility, ash, minerals, polar fox.

Roman SZYMECZKO, Anna PIOTROWSKA, Monika BOGUSŁAWSKA-TRYK, Department of Animal Physiology, University of Technology and Agriculture, Mazowiecka 28, 85-084 Bydgoszcz, Poland.
E-mail: romansz@atr.bydgoszcz.pl

Minerals determine animal growth, development, reproduction and health. They are part of the tissues and body fluids. They are components or activators of numerous hormones, enzymes and vitamins. When combined with proteins, they allow for maintaining cellular oxidation activity and oxygen transport, determining the right metabolic processes (NRC 1980; KING *et al.* 2001; VASKONEN 2003). Absorption of minerals depends on the type and composition of the diet. The absorption of bioelements depends on the chemical form of the component, its deficit or surplus in feed, the quantitative ratio and the presence of factors activating or inhibiting absorption (DELZENNE *et al.* 1995; BRONNER & PANSU 1999; LIU *et al*. 2000; BURKHALTER *et al.* 2001; HILL *et al.* 2001).

The alimentary canal in carnivorous fur animals is short and shows a simple structure, adapted to the concentrated and highly-energetic feeds of animal origin. Traditionally the digestibility of nutrients in carnivorous animals is determined along the entire alimentary canal. Experiments on different monogastric animal species showed that the processes of nutrient fermentation and endogenous secretion observed in the large intestine caused by bacterial enzymes affect the concentration of minerals in the large intestine digesta (LARSEN & SANDROM 1993; DINTZIS *et al.* 1995; WOLF *et al.* 1998; HILL *et al*. 2001). Similarly research on mink demonstrated that, despite a short digesta passage time and a considerably lower bacterial activity, as compared with other species of monogastric animals, in these animals the large intestine shows processes of microbiological degradation of carbohydrates and endogenous secretion (BØRSTING *et al*. 1995; WILLIAMS *et al.* 1998; LAERKE *at al.* 2004). These processes can affect the right estimation of the amount of nutrients absorbed by the animal. The intestinal method of estimating the apparent digestibility eliminates the effect of these processes and, as compared with the faeces method, is more precise, informing directly about the bioavailability of minerals ingested with feed. In an experiment which involved cannulated dogs, HILL *et al.* (2001) defined the ileal digestibility of minerals from diets with a different amount of animal and plant protein. However, no

*Supported by the Polish State Committee for Scientific Research (KBN), Project No. 5PO6E02618.

reports on the ileal digestibility of minerals in polar foxes were found in the literature available.

The aim of the present study was to compare the content and apparent ileal digestibility of ash and minerals in feeds used in feeding reproductive polar foxes during the non-mating period on two domestic farms differing in reproductive results in the preceding breeding cycle.

Material and Methods

Experimental animals

The experiment included 5, from the same litter, one-year-old male polar foxes of a similar body weight (6.18±0.15 kg). In these animals 'end-to--end' ileorectal anastomosis was made surgically following the method developed in foxes by SZYMECZKO (2001). Foxes were premedicated with tranquilizer (0.08 ml kg^{-1}) and atropine (0.03 mg kg^{-1}). General anaesthesia was induced with ketamine (10 mg kg^{-1}) and foxes were placed on their back side for the surgical procedure. The abdominal cavity was opened and the marked segment of large intestine for resection was located. In the mesentery anastomosed to it – successive blood vessels were ligated and then the segment of the large intestine was resected. Free sections of ileum and rectum were anastomosed with two continuous sutures with the 'end-to-end' technique. Having completed the anastomosis, the ends of the free mesentery and body layers were sutured, the area around the wound was washed and disinfected. Over five days following the operation, antibiotics and tranquilizers, antihaemorrhage and anti-swelling medications were administered to the foxes with dosages recommended by the producers. During the first two days after surgery, liquids were supplemented, administering subcutaneous physiological saline solution and glucose. During the following days the foxes were fed with a liquid diet with an increasing concentration of nutrients and from the tenth day, the animals were given an entire feed ration. After the veterinary examination in the third week after the operation, the foxes were considered clinically healthy. They were housed separately in metabolic cages, in an environmentally controlled room at 18°C and a 14-10 hours light-dark cycle. The use and handling of animals for this experiment were approved by the Local Ethical Committee in Bydgoszcz.

Experimental diets

The digestibility of ash and minerals in diets used in polar fox nutrition were carried out on two domestic breeding farms (A and B) over the non-mating period (July 15-December 1). On farm A the best (8.1 kits per female), and on farm B – the worst (1 kit per female) reproductive results in the 1999/2000 season were recorded. The ingredient compositions of feeds given in the first feeding period from July 15- September 15 (regeneration after reproduction period – diets A1 and B1) and in the second feeding period from July 15 to December 1 (winter furring period – diets A 2 and B2) are shown in Table 1. The diets were based on animal offal, with the farm A feed composition diversified, while farm B feeds were based exclusively on beef offal and pre-cooked barley meal. The diets used in digestibility experiments contained 0.5% of chromic oxide (SZYMECZKO & BURLIKOWSKA 1996). Foxes were fed once a day at 8 a.m., at the amount covering their metabolizable energy requirements: 90 kcal ME kg^{-1} of body weight (NRC 1982) and had free access to water.

Digestibility experiment

Testing each diet was divided into two 4-day periods; preliminary, constituting a period of animal adaptation to the feeds investigated and a period of continuous 96-hour ileal digesta collection. All the experimental digesta was immediately collected after being excreted into plastic boxes with tightly fitting lids kept on ice trays which were stored at +4°C between successive daily collections. After collection of digesta, the containers were stored at –25°C before being analysed.

Chemical analysis

The ileal digesta and feed samples were freeze-dried. The content of nutrients in feeds was determined with standard methods. The content of minerals in diets and ileal digesta were determined after a prior sample mineralization (20 min) in the nitric and perchloric acids medium at 230°C using the Milestone Ethos Plus Microwave Labstation. In the samples the contents of calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and chromium (Cr) were determined using the atomic absorption spectrophotometer 969 by Unicam, applying adequate wavelengths: Ca – 422.7 nm, Mg – 285.2 nm, Na – 589 nm, K – 766.5 nm and Cr – 357.9 nm. The content of phosphorus (P) was determined with the colorimetric method at a wavelength of 420 nm (SAPEK & SAPEK 1997). The digestibility of crude ash and minerals was defined with the indicator method (BURACZEWSKI & ZIOŁECKA 1991).

Statistical analysis

The results obtained were verified with statistical analysis with the Student's *t*-test for dependent

Table 1

Composition of diets (%) fed to polar foxes on farm A (diet A1 and A2) and B (diet B1 and B2) over the non-mating period

Feeding period	15.07-15.09.		15.09-01.12.	
Diet	A1	B1	A2	B2
Beef offal	–	69.9	–	78.3
Poultry offal	42.0	–	44.0	–
Fish offal	29.9	–	29.4	–
Meat meal	7.0	–	7.4	–
Blood and feather poultry meal	–	–	2.9	–
Milk powder	2.0	–	1.0	–
Rapeseed oil	–	–	1.2	–
Extruded cereals	15.0	–	8.9	–
Precooked barley	–	30.0	–	21.6
Fibre mixture (Norpol)	4.0	–	–	–
Wheat bran	–	–	2.2	–
Vegetables	–	–	2.9	–
Vit.-min. mixture [(1)] (Ewomix)	–	0.05	–	0.05
Vit.-min. mixture [(2)] (Polfamix LN)	0.1	–	0.1	–
Iron preparation [(3)] (Taiga Fur)	–	0.05	–	0.05

[(1)] Concentration per 1g of mixture: vit. A 7200 j.m; D_3 720 j.m; E 82 mg; B_1 30.8 mg; B_2 12 mg; H 0.1 mg; B_6 6 mg; B_{12} 0.04 mg; PP 20.4 mg; folic acid 0.6 mg; Ca-panthotenate 8 mg; choline chloride 50 mg; Mg 66.8 mg; Mn 6 mg; Zn 8.6 mg; Cu 1 mg; Fe 9.2 mg; J 0.3 mg;
[(2)] Concentration per 1g of mixture: vit. A 3500 IU; D_3 500 IU; E 28 mg; K_3 0.2 mg; B_1 1.5 mg; B_2 2.8 mg; B_6 2.8 mg; B_{12} 0.02 Mg;H 0.2 mg; folic acid 0.2 mg; PP 10 mg; Ca-panthotenate 7 mg; methonine 200 mg; choline chloride 50 mg; Fe17 mg; Zn 2 mg; Cu 1 mg; Mn 1 mg; Co 1 mg; J 0.1 mg; Se 0.6 mg;
[(3)] Concentration per 1 ml of preparation: ferrous glukonate 205 mg; ferrous sulfate 97.5 mg; cupric sulfate 5.9 mg; cobalt sulfate 1.76 mg.

samples using Statistica software (1998). The level of significance was set at $P<0.05$.

Results and Discussion

The chemical composition of feeds and the content of minerals in the dry matter of diets are given in Table 2. The content of nutrients in diet A during both feeding periods was similar, while diet B showed an increased concentration of protein (by about 22%) and crude ash (by about 23%) over the winter furring period (September 15-December 1). The differences in the content of nutrients between A and B farm feeds were found mainly in fat, carbohydrates and crude ash. The greatest differences between diets were demonstrated in the concentration of crude ash whose content in diets A was over 3-fold higher than its amount in diets B and exceeded the nutrient requirements recommended for this animal species (NRC 1982). A high content of crude ash in the diet fed on farm A in both feeding periods examined agree well with a higher content of calcium, phosphorus and sodium in that feed, accompanied by a relatively balanced amount of magnesium and potassium in both diets. As compared with the polar foxes feeding recommendations for the non-mating period, diet A showed an excessive concentration of calcium and sodium, while diet B was a deficient feed as far as the content of calcium and phosphorus in both breeding periods was concerned (NRC 1982; SŁAWOŃ 1987; JAROSZ 1994).

The digestibility results presented in Table 3 showed a higher apparent ileal digestibility of ash and the macroelements investigated (except for sodium) from feeds used in polar fox nutrition on farm B in both feeding periods. As for most of the parameters analyzed, the differences were statistically significant ($P<0.05$). Sodium absorption, measured at the end of the ileum, was higher ($P<0.05$) from diets A1 and A2 composed of poultry and fish offal. A high content of ash in diets can lower not only the digestibility of basic nutrients but also the absorption of minerals (SŁAWOŃ 1987; ROUVINEN & KIISKINEN 1991), which is confirmed by the present results. A high degree of variation in the crude ash digestibility in diets A

Table 2

Chemical content of nutrients and mineral composition of diets fed to polar foxes on farm A (diet A1 and A2) and B (diet B1 and B2)

Feeding period	15.07 -15.09.		15.09-01.12.	
Diet	A1	B1	A2	B2
Dry matter, g kg^{-1}	941.9	958.5	959.5	962.9
			g kg^{-1} dry matter	
Crude protein	351.3	338.3	380.0	414.4
Crude fat	209.0	232.1	213.4	298.1
Crude carbohydrates	203.6	296.6	190.1	178.3
Crude Ash	163.7	51.5	159.3	54.3
			g kg^{-1} dry matter	
Calcium	35.10	2.04	36.39	2.20
Phosphorus	7.19	1.96	7.19	2.18
Magnesium	1.74	1.78	2.29	1.47
Sodium	15.50	4.59	14.70	4.75
Potassium	5.80	6.08	5.49	6.48

Table 3

Apparent ileal digestibility of crude ash and minerals (%) in diets fed to polar foxes on farm A (diet A1 and A2) and B (diet B1 and B2)

Feeding period	15.07-15.09.		15.09-01.12.	
Diet	A1	B1	A2	B2
Ash	11.40 ± 3.10 [1)]	23.50 ± 3.80*	13.90 ± 1.60	33.30 ± 3.20*
Calcium	19.52 ± 11.23	21.44 ± 11.84	17.74 ± 5.39	53.10 ± 8.58*
Phosphorus	46.33 ± 2.52	63.26 ± 5.36*	41.65 ± 6.86	76.67 ± 2.19*
Magnesium	0.90 ± 9.24	53.96 ± 6.89*	12.46 ± 12.39	56.23 ± 10.23*
Sodium	78.99 ± 4.71	52.25 ± 13.38*	79.19 ± 2.88	66.82 ± 9.58*
Potassium	75.10 ± 4.25	81.49 ± 5.24	57.02 ± 4.64	86.44 ± 6.57*

[(1)] Results are expressed as mean value ± SD

* Means in the same feeding period differ significantly ($P<0.05$)

and B agree well with the results reported by other authors. AHLSTRØM *et al.* (2003) and AHLSTRØM & SKREDE (1998), estimating the total digestibility of nutrients in foxes from diets rich in carbohydrates and commercial pet food in which the concentration of crude ash ranged from 6 to 7%, recorded ash digestibility coefficient values ranging from 34 to 58%.

The degree of utilization of calcium and phosphorus from feeds depends on the right ratio of these macroelements. An optimal calcium to phosphorus ratio in fox feeds is 1:1 to 1.7:1, and rations outside this range may result in improper growth of bone, even when the diet contain large amounts of vitamin D (NRC 1982). Both an increase in the content of ash and widening of the Ca: P ratio show an adverse effect on the absorption of these elements, which is conformed by the present results. A lower apparent ileal digestibility of calcium and phosphorus in both feeding periods was observed for the farm A diets, showing a high concentration of ash and a widened ratio of Ca: P (4.9:1 diet A1; 5.1: 1 diet A2). This relationship is confirmed by VALAJA *et al.* (2000), who, investigating growing foxes, and observed the highest digestibility of calcium (19.9%) and phosphorus (50.9%), measured throughout the alimentary canal of these animals when the foxes were fed with diets with a low content of ash (47g kg^{-1} DM) and 1.4: 1 Ca : P ratio.

The literature available shows no reports on macroelement ileal digestibility in polar foxes. HILL *et al.* (2001), reporting on an experiment which involved cannulated dogs fed with a 100% beef protein diet, show a considerably lower apparent ileal digestibility of phosphorus (25.9%), sodium (36.8%) and magnesium (12.4%) and a greater ileal digestibility of potassium (92.9%), as compared with the digestibility of these macroelements from experimental feeds B1 and B2 in which beef offal was the main ingredient of the di-

ets. The differences are most probably due to the diet composition and a different bioavailability of the diet minerals (DELZENNE *et al.* 1995; BURKHALTER *et al.* 2001; HILL *et al*. 2001).

The present study shows that an excessive content of crude ash in feeds used in the polar foxes feeding over the non-mating period (diets A) decreased the digestibility of both ash and the macroelements estimated. The literature available offers no data on mineral digestibility in foxes, which suggests a need for further research which would provide data to facilitate defining their optimal level in diets for this animal species. The present results constitute a basis for further research into the ileal digestibility of both macroelements and microelements in polar foxes, using the 'end-to--end' ileorectal anastomosis method.

References

AHLSTRØM Ø., FUGLEI E., MYDLAND L. T. 2003. Comparative nutrient digestibility of arctic foxes (*Alopex Lagopus*) on Svalbard and farm-raised blue foxes (*Alopex Lagopus*). Comp. Biochem. Physiol. A **134**: 63-68.

AHLSTRØM Ø., SKREDE A. 1998. Comparative nutrient digestibility in dogs, blue foxes, mink and rats. J. Nutr. **128**: 2676-2677.

BØRSTING C. F., KNUDSEN K. E. B., STEENFELDT S., MEJBORN H., EGGUM B. O. 1995. The nutritive value of decorticated mill fractions of wheat. 3. Digestibility experiments with boiled and enzyme treated fractions fed to mink. Anim. Feed Sci. Tech. **53**: 317-336.

BRONNER F., PANSU D. 1999. Nutritional aspects of calcium absorption. J. Nutr. **129**: 9-12.

BURACZEWSKI S., ZIOŁECKA A. 1991. Principles of Animal Nutrition and Feed Sciences. Omnitech Press. Warszawa, Poland. (In Polish).

BURKHALTER T. M., MERCHEN N. R., BAUER L. L., MURRAY S. M., PATIL A. R., BRENT J. L., FAHEY G. C. 2001. The ratio of insoluble to soluble fiber components in soybean hulls affects ileal and total-tract nutrient digestibilities and fecal characteristics of dogs. J. Nutr. **131**: 1978-1985.

DELZENNE N., AERTSEENS J., VERPLAETSE H., ROCCARO M., ROBERFROID M. 1995. Effect of fermentable fructo-oligosaccharides on mineral, nitrogen and energy digestive balance in the rat. Life Sci. **57**: 1579-1587.

DINTZIS F. R., LASZLO J. A., NELSEN T. C., BAKER F. L., CALVERT C. C. 1995. Free and total ion concentrations in pig digesta. J. Anim. Sci. **73**: 1138-1146.

HILL R. C., BURROWS C. F., ELLISON G. W., BAUER J. E. 2001. The effect of texturized vegetable protein from soy on nutrient digestibility compared to beef in cannulated dogs. J. Anim. Sci. **79**: 2162-2171.

JAROSZ S. 1994. Nutrient requirements of carnivorous and herbivorous fur animals The Kielanowski Institute of Animal Physiology and Nutrition eds. Jabłonna, Poland. (In Polish).

KING J.C. 2001. Effect of reproduction on the bioavailability of calcium, zinc and selenium. J. Nutr. **131**: 1355-1358.

LAERKE H. N., HEJLESEN C., HEDEMANN M. S. 2004. Physico-chemical properties of different carbohydrate source in the gut of mink. Proc. VIII Intern. Sci. Congress in Fur Animal Production, 's-Hertogenbosch, The Netherlands, 15-18 September, Scientifur **28**: 110-115.

LARSEN T., SANDSTROM B. 1993. Effect of dietary calcium level on mineral and trace element utilization from a rapeseed (*Brassica napus L.*) diet fed to ileum-fistulated pigs. Br. J. Nutr. **69**: 211-224.

LIU J., BOLLINGER D. W., LEDOUX D. R., VEUM T. L. 2000. Effects of dietary calcium:phosphorus ration on apparent absorption of calcium and phosphorus in small intestine, cecum, and colon of pigs. J. Anim. Sci. **78**: 106-109.

NRC 1980. Mineral tolerance of domestic animals. National Academy of Sciences ed., Washington D.C.

NRC 1982. Nutrient Requirements of Mink and Foxes. 2 nd revised edition. National Academy Press ed., Washington D.C.

ROUVINEN K., KIISKINEN T. 1991. High dietary ash content decreases fat digestibility in the mink. Acta Agric. Scand. **41**: 375-386.

SAPEK A., SAPEK B. 1997. Methods of chemical analysis of organic soil. IMUZ Falenty ed., Poland. (In Polish).

SŁAWOŃ J. 1987. Fox and mink nutrition PWRiL Warszawa, Poland. (In Polish).

SZYMECZKO R. 2001. Ileal and total digestibility of amino acids in feeds used in mink and polar fox nutrition. J. Anim. Feed Sci. (Suppl.1) **10**: 211-222.

SZYMECZKO R., BURLIKOWSKA K. 1996. Protein digestion in the digestive tract of polar foxes. Scientifur **20**: 203-208.

VALAJA J., PÖLÖNEN I., JALAVA T., PERTTILÄ S., NIEMELÄ P. 2000. Effects of dietary mineral content on mineral metabolism and performance of growing blue foxes. Scientifur **24**: 28-31.

VASKONEN T. 2003. Dietary minerals and modification of cardiovascular risk factors. J. Nutr. Biochem. **14**: 492-506.

WILLIAMS C., ELNIF J., BUDDINGTON R. K. 1998. The gastrointestinal bacteria of mink (*Mustela vison* L): influence of age and diet. Acta Vet. Scand. **39**: 473-482.

WOLF B. W., FIRKINS J. L., ZHANG X. 1998. Varying dietary concentration of fructooligosaccharides affect apparent absorption and balance of minerals in growing rats. Nutr. Res. **18**: 1791-1806.