Diet effect on short- and long-term glycaemic response in adult healthy cats

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Cat,
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High protein diet.

Summary
In the paper the short- and long-term glycaemic response after 4 diet programmes was evaluated. Each diet programme was alternatively administered to 6 healthy cats for 30 days. At the end of each period cats were weighed and underwent blood sampling for glucose and fructosamine determination. Glycaemia was measured every 2 hours for 24 hours using an automated glucometer. Very high protein level and low starch (VHP/LS) and high protein and moderate starch level (HP/LS) diets showed glucose (Mean and Peak) and fructosamine values significantly lower compared to the moderate protein and high starch diets (MP/HS). It is likely that these results are due to the contemporary effect of the following nutritional characteristics: protein level, protein/starch ratio and dietary fibre. All these parameters were higher in VHP/LS and HP/MS diets. These preliminary results suggest that the use of diets with high protein/starch ratio and soluble fibre levels favours the carbohydrate metabolism of healthy cats.

Effetto della dieta sulla risposta glicemica post-prandiale nei gatti adulti

Parole chiave
Dieta iperproteica,
Fibra dietetica,
Gatto,
Glicemia.

Riassunto
Scopo della ricerca è stato valutare la risposta glicemica in gatti adulti sottoposti a 4 trattamenti nutrizionali. Ogni dieta è stata somministrata alternativamente a 6 gatti adulti in buono stato di salute. Al termine di ciascun periodo di prova i gatti sono stati pesati e sottoposti a prelievo ematico per la determinazione del glucosio e delle fruttosamine. La glicemia è stata misurata per 24 ore consecutive ad intervalli regolari di 2 ore, mediante l'impiego di un glucometro automatizzato. La dieta con un alto livello di proteine e povera in amido (VHP/LS) e quella ad alto tenore proteico e con moderato tenore in amido (HP/LS) hanno fatto riscontrare livelli di glucosio (medio e di picco) e delle fruttosamine significativamente inferiori rispetto alle due diete MP/HS con più alto contenuto in amido. Le risposte glicemiche riscontrate sono verosimilmente da ascriversi all'effetto combinato delle seguenti caratteristiche nutrizionali: tenore proteico, rapporto proteine/amido e fibra dietetica. Tutti questi parametri sono risultati più elevati nelle diete VHP/LS e HP/MS. I risultati indicano che l'uso di diete con un elevato rapporto proteine/amido e alti livelli di fibra solubile favoriscono il metabolismo dei carboidrati in gatti sani.

Introduction

In the last 30 years, the prevalence of obesity and diabetes mellitus in cats increased by more than 10 % as reported by Lutz (Lutz 2008), whereas the fatality rate progressively decreased from 40% to 10%, probably due to the greater knowledge of the pathogenic mechanisms that underline the disease onset (Prahl *et al.* 2007). Feline diabetes mellitus was highly related with obesity because it is directly associated with insulin resistance (Lutz and Rand 1995). As a consequence, specific dietary modifications are important aspects both to prevent and cure diabetes mellitus (Mori *et al.* 2009), thus making the specification of appropriate diet for diabetic cats one of the major strategies in diabetes management. The major aims of this approach are to reduce body weight, improve glycaemic control and reduce the risk of insulin resistance development, and changes in lipid profile (Bouchard and Sunvold 2000). As described by Hoening (Hoening 2012), these changes are similar to those observed in humans during the metabolic syndrome, although the higher risk of artery disease, stroke and hypertension were not observed in cats.

Carbohydrates, in particular starch, represent 30-60% of pet-food (Carciofi *et al.* 2008). In carnivores starch digestibility is highly variable and is affected by several factors, such as sources, particle size, amylose/amylopectin ratio, and gelatinization process. However, dogs and cats digest starch almost completely (Svihus *et al.* 2005). Starch is the main nutrient affecting post-prandial glucose and insulin responses in dog and cat (de-Oliveira *et al.* 2008), other dietary factors affecting these responses are protein/starch ratio, dietary fibre, and fatty acid profile (Carciofi *et al.* 2008).

Few reports concerning the influence of diet composition in feline glycaemic response are available (Hoening *et al.* 2007, Mori *et al.* 2009), most of them focus on diabetic felines. As a consequence only little information is available on the diet composition effects on post-prandial glucose response in healthy adult cats. The aim of this study was to compare the post-prandial glucose and fructosamine concentrations in healthy felines using different diet programmes formulated for adult cat maintenance.

Materials and methods

For the trial, 6 neutered European adult cats in healthy conditions [weight 4.6 ± 0.3 kg, BCS (9 point scale) 5.7 ± 0.5, age 3.5 ± 0.2 years] were utilized. Throughout the entire experimental period (30 days x 4 diet programmes), the cats continued to live with their adoptive families following their usual habits with the only exception of the administered diet. In order to determine the daily food intake the owners received a record card where they daily indicated the administered food amounts and the refusals.

Four extruded commercial diets with the following characteristics were used: very high protein level and low starch from potatoes (VHP/LS); high protein and moderate starch levels from oats and spelt (HP/MS); and 2 traditional diets characterised by moderate protein content and high starch concentration from rice and corn (MP/HS1 and MP/HS2). The chemical composition of each diet was determined according to AOAC methods (Association of Official Analytical Chemist 2006.). The dietary fibre fractions were determined according to the methods proposed by Prosky and colleagues (1985; 1992). The energy density (kcal ME/kg) was estimated from chemical parameters.

All diet programmes were alternatively administered (100 kcal ME/kg$^{0.67}$/d) for 30 days to each cat (10 adaptation + 20 trial) according to a 6 x 4 randomized design. At the end of each period, the cats were not fed overnight, were weighed and a catheter was placed in order to collect blood samples. Serum fructosamine was determined using a kit (cod. 90009660, Seac Radim Company, Florence, Italy) and a spectrophotometer (Helios Gamma, Thermo, Rochester, New York, USA).

In order to evaluate the short-term glycaemic response, serum glucose levels were determined each 2 hours for 24 hours (12 samplings) using an automated glucometer (Cera-Pet, Mod. G300V, Ceragem Medisis, Jongin, South Korea). During such evaluation the diet of interest was supplied at 8:00 am in ratio of 50% of daily requirements (50 kcal ME/kg$^{0.67}$) and after the 6th evaluation other 50 kcal ME/kg$^{0.67}$ of diet were administered for 30 minutes, refusals were weighed in order to estimate feed intake.

Glucose (mean and peak amounts) and fructosamine values were statistically analysed by ANOVA using the Proc. GLM of SAS[1] in order to evaluate the diet effects according the following equation:

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

where y_i is the dependent variable, μ is the mean, α is diet effect (i: VHP/LS, HP/MS, MP/HS1 and MP/HS2) and ε is the error term.

Results

The main nutritional characteristics of the diets are reported in Table I. As expected, VHP/LS and HP/MS

[1] SAS/STAT® Software 2000. Changes and Enhancements through Release 8.1. SAS Institute Inc, Cary, NC, USA. SAS, 2000.

diets showed values for crude protein and P/S ratio higher than both MP/HS diets considered in this study.

Both diets richer in protein showed the higher contents of total dietary fibre amounts. However, only the HP/MS diet showed also the highest values for the soluble dietary fibre.

Body weight was approximately constant during the trial (4.7, 4.7, 4.6, and 4.6 kg, using diets HP/MS, VHP/LS, MP/HS1, and MP/HS2 diets, respectively). No significant difference was registered in feed intake either during the adaptation period (93.76, 94.20, 92.89, and 91.78 kcal ME/kg$^{0.67}$, using diets MP/HS1, MP/HS2, HP/MS, and VHP/LS diets, respectively) or during the 24 hours of observation (37.5, 38.11, 36.33, and 36.76 kcal ME/kg$^{0.67}$, MP/HS1, MP/HS2, HP/MS and VHP/LS and diets, respectively). However, the glycaemic response (Table II) showed significant differences for both mean and peak values.

A similar trend was observed for fructosamine values. Although in this case, significant differences were observed between the diets MP/HS 1 and 2 and between VHP/LS and HP/MS.

Figure 1 shows the average blood glucose curves observed when the 4 diets were administered. The diets characterised by the lowest P/S ratios showed the larger oscillations in glycaemic values.

Discussion

In this study, the glycaemic response under the influence of 4 diets were assessed and compared in healthy cats, in order to understand the implications of the chemical composition of commercial diets over some traits of the carbohydrate metabolism of cats.

Even if all the registered glycaemic and fructosamine levels were in the normal ranges, VHP/LS and HP/MS diets showed the lowest peak and mean glycaemic values. These preliminary results suggest that diet ingredients and chemical compositions affect some traits of the carbohydrate metabolism of cats. Indeed, previous studies demonstrated that a high protein diet could reduce weight gain and post-prandial glucose levels, thereby improving overall glucose control, in humans (Gannon and Nuttall 2004, Gannon *et al.*

Table I. *Main ingredients and nutritional characteristics of the four diet programmes administered to each cat for 30 days.*

Diet	VHP/LS	HP/MS	MP/HS1	MP/HS2
Nutrients	Ingredients			
Protein	Dried chicken, eggs, herrings	Dried chicken, eggs, herrings	Dried chicken, fish, eggs, corn gluten feed, hydrolysed protein	Dried chicken, corn gluten feed, hydrolysed protein
Starch	Potatoes	Spelt, oat	Rice, corn	Corn, rice
Lipid	Chicken fat, fish oil	Chicken fat, fish oil	Fish oil, seeds oil	Animal fat, soy oil, fish oil
Structural carbohydrates	Pea fibre, carrots, alfalfa, inulin, FOS, MOS, psylium	Beet pulp, carrots, pea fibre, alfalfa, inulin, FOS, MOS, psylium	Beet pulp, pea fibre, inulin, FOS, yeast	Vegetable fibre, beet pulp, yeast
	% a.f.			
Crude Protein	42	33	28	29
Starch	17	26	34	35
Ether Extract	22	22	16	17
Protein/Starch	2.5	1.3	0.8	0.8
TDF	20	20	16	15
SDF	4.34	4.70	4.08	3.78
IDF	15.66	15.30	11.92	11.22
ME (kcal/kg)	3,824	3,870	3,606	3,700

VHP/LS = very high protein and low starch; HP/MS = high protein and moderate starch; MP/HS1 and MP/HS2 = moderate protein and high starch; TDF = total dietary fibre; SDF = soluble dietary fibre; IDF = insoluble dietary fibre.

Table II. *Glucose (mean and peak) and fructosamine levels registered after the four diet programmes administered to each cat for 30 days.*

Diet	VHP/LS	HP/MS	MP/HS1	MP/HS2
Cats	6	6	6	6
Mean glucose (mg/dl)	$62.83^{b} \pm 5.41$	$67.64^{b} \pm 3.71$	$74.03^{a} \pm 6,20$	$74.67^{a} \pm 3.48$
Peak glucose (mg/dl)	$71.33^{B} \pm 4.27$	$72.86^{B} \pm 4.70$	$83.40^{A} \pm 3.52$	$82.57^{A} \pm 3.91$
Fructosamine (µmol/l)	$246^{b} \pm 15$	$318^{a,b} \pm 12$	$333^{a} \pm 10$	$347^{a} \pm 15$

VHP/LS = very high protein and low starch; HP/MS = high protein and moderate starch; MP/HS1 and MP/HS2 = moderate protein and high starch; A, B = P <0.01; a, b = P <0.05.

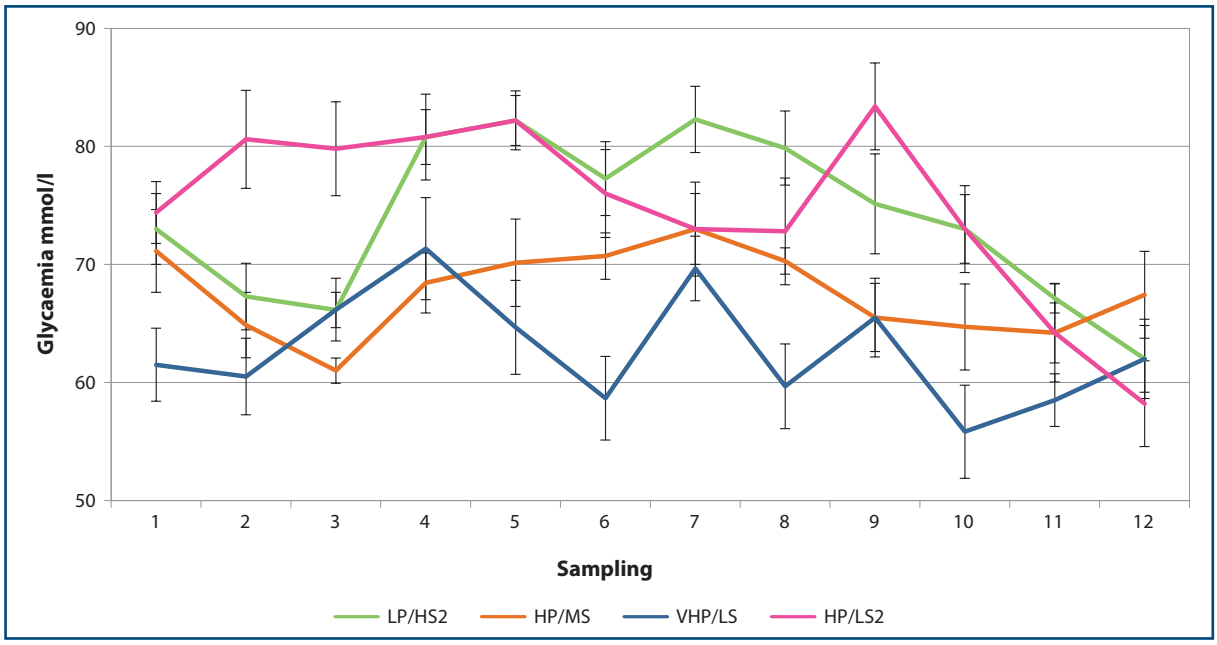

Figure 1. *Mean glycaemic curve obtained using the 4 diet programmes administered to each cat for 30 days.* VHP/LS = very high protein and low starch; HP/MS = high protein and moderate starch; MP/HS1 and MP/HS2 = moderate protein and high starch.

2003) and felines (Frank *et al.* 2001) suffering from type 2 diabetes. In the scientific community there is a debate about the effects of high-protein diets on insulin production. Some studies report increased insulin levels (Usami *et al.* 1982), while others do not (Gannon et al 2003, Sargrad *et al.* 2005). In our opinion, the long-term administration to healthy cat of high-energy diets, largely composed by highly digestible carbohydrates, leads high post-prandial glycaemic levels and increases fructosamine value, whereas the administration of diets characterised by similar energy density but with higher protein levels, might result in lower glucose and fructosamine values. The reduction of post-prandial glycaemic levels and fructosamine values were also due to the high soluble dietary fibre concentration of VHP/LS and HP/MS diets. Indeed, as described by Mori and colleagues (Mori *et al.* 2009), dietary fibre, which is indigestible but fermentable into the large intestine of carnivores (Calabrò *et al.* 2012), contributes to decrease glucose absorption and insulin requirements. Even if mechanisms are still unknown, soluble dietary fibres seem to affect the nutrient transit rate into the gut, thus reducing glucose absorption post-prandial glycaemia and, consequently, enhancing the glycaemic control (Costacou and Mayer-Davis 2003, Feldman and Nelson 2004).

However, the higher glycaemic values registered when both MP/HS diets were fed could confirm the hypothesis that carnivores, and in particular felines, are not well adapted to readily metabolize large amounts of glucose as suggested by the results of Miller and Colagiuri (1994). Even if the glucose and fructosamine levels registered during this trial were always in the physiological range, the administration of high protein diets proved to modulate post-prandial glycaemic response. The effect on carbohydrates metabolism were also proved by the lower fructosamine levels (Thiess *et al.* 2004).

Conclusions

These preliminary results suggest that the administration of diets characterised by high protein and dietary fibre amounts alters glucose response in cats. The meaning and health implications of this finding require further investigation. In particular, post-prandial insulin response needs to be investigated in order to assess the effects of the administration of high protein low starch diets.

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