39   **Abstract**

40   **Background**

41   Obesity in dogs and cats is usually managed by dietary energy restriction

42   using a purpose-formulated weight loss diet, but signs of hunger and begging

43   commonly occur causing poor owner compliance. Altering diet characteristics

44   so as to reduce voluntary food intake (VFI) can improve the likelihood of

45   success, although this should not be at the expense of palatability. The aim

46   of the current study was to compare the VFI and palatibility of novel

47   commercially available canine and feline weight loss diets.

48

49   **Methods**

50   The relative performance of two canine (C1 and C2) and two feline (F1 and

51   F2) diets was assessed in groups of healthy adult dogs and cats, respectively.

52   Diets varied in energy, protein, fibre, and fat content. To assess canine VFI,

53   12 (study 1) and 10 (study 2) dogs were offered food in 4 meals, for 15

54   minutes on each occasion, with hourly intervals between the meals. For feline

55   VFI, 12 cats were offered food *ad libitum* for a period of 18 hours per day over

56   5 consecutive days. The palatability studies used separate panels of 37 dogs

57   and 30 cats, with the two diets being served, side-by-side, in identical bowls.

58

59   **Results**

60   In dogs, VFI was significantly less for diet C1 than diet C2 when assessed on

61   energy intake (study 1, 42% less, P=0.032; study 2, 28% less, P=0.019), but

62   there was no difference in gram weight intake (study 1: P=0.964; study 2:

63   P=0.255). In cats, VFI was 17% less for diet F1 than diet F2 when assessed

64   by energy intake ($P<0.001$), but there was again no difference in gram weight

65   ($P=0.207$). There was no difference in palatability between the two canine

66   diets ($P=0.490$), whilst the panel of cats diet preferred F1 to F2 ($P<0.001$).

67

68   **Conclusion**

69   Foods with different characteristics can decrease VFI without affecting

70   palatability in both dogs and cats. The effects seen could be due to

71   decreased energy content, decreased fat content, increased fibre content,

72   different fibre source, and increased protein content. Further studies are now

73   needed to determine whether similar findings occur in obese dogs and cats on

74   controlled weight loss programmes.

75

Background

Obesity is now a common medical disorder in both dogs and cats, and has various effects on the health of animals of both species [1,2,3,4,5]. Controlled weight loss has been shown to have a number of benefits in previously obese dogs, including improved mobility [6], improved respiratory function [4], resolution of metabolic disturbances [7,8], and improved quality of life [5]. Dietary energy restriction using a purpose-formulated diet is the most common approach for inducing weight loss, and such strategies are usually very successful in experimental trials in both dogs [9,10,11] and cats [12,13]. However, the same strategies do not perform as well in a clinical setting, for obese client-owned pets, with slower rates of weight loss observed despite marked energy restriction [14,15,16,17]. Further, many dogs and cats do not successfully reach their target weight, and this is most often because owners struggle to comply with the programme ultimately deciding to stop [18,19]. A common problem that owners encounter is the fact that dietary energy restriction causes hunger, which causes increased begging and scavenging activity in their dog or cat. Such behaviour can be difficult for the owner to resist, ultimately leading to poor compliance. Indeed, recent studies have indicated that many owners feed additional food during a controlled weight loss programme despite veterinary recommendations [14,15].

Food manufacturers can alter a range of dietary characteristics, and such changes can affect voluntary food intake (VFI). For example, a weight management diet can be changed so as to reduce VFI, and such a modification should increase the likelihood of success, provided that it does

101   not adversely affect palatability and, therefore, overall diet acceptance.

102   Approaches that can be used in dogs and cats include decreasing nutrient

103   density, for instance by expanding kibble volume with air [20] or water [21],

104   and altering the macronutrient content of the diet by increasing protein and/or

105   fibre content [22,23]. In addition to caloric dilution, adding dietary water can

106   increase voluntary physical activity and may have added benefits for weight

107   loss [21]. With regard to macronutrient content, recent studies have indicated

108   that a diet containing increased amounts of both protein and fibre are more

109   effective at reducing VFI than diets containing increased amounts of these

110   macronutrients individually [22], and have shown that such diets lead to

111   improved outcomes of weight loss in obese pet dogs [17]. In cats, the ideal

112   balance of protein and fibre is more difficult to optimise because very high

113   protein diets can actually stimulate VFI in cats, whilst very high fibre diets can

114   be unpalatable [23]. Despite this, dry diets that combine moderately

115   increased protein and fibre content are better at reducing begging activity in

116   obese cats during a controlled weight loss programme [16].

117

118   Given the importance of obesity as a medical disease, and the recognition

119   that current strategies are not perfect [18], there has been a great deal of

120   recent interest in improving diets for controlled weight loss so as to improve

121   outcomes. Indeed, in the last five years, new diets have been developed and

122   become commercially available [24,25], and many existing commercial weight

123   loss diets have been reformulated [18]. As a result, there is a need to assess

124   the efficacy of diets that are currently available. Therefore, the aim of the

125   current study was to compare the performance, in terms of VFI and

126   palatability, of novel commercially-available canine and feline weight loss

127   diets, in groups of healthy dogs and cats housed in research colonies.

128

Methods

Research sites and study animals

The studies were undertaken between January 2014 and July 2014 at two

sites: the Royal Canin Research Center, Aimargues, France (Site 1), and the

National Veterinary School of Nantes, Food Science and Engineering,

(ONIRIS) France (Site 2). The first canine VFI study, the feline VFI study, and

both the feline and canine palatability studies were all performed at site 1; the

second canine VFI study was performed at site 2. The participating cats and

dogs were colony animals; those from site 1 were sourced from private

breeders, whilst those from site 2 were born and raised at research site itself.

All animals were deemed to be healthy prior to the start of the study, based

upon health checks (comprising physical examination), and clinicopathological

assessments (e.g. blood chemistries and complete blood counts), conducted

on a monthly and annual basis, respectively. All remained healthy during the

studies, with no adverse events were reported, and no modifications to any of

the experimental protocols were required. Faecal consistency also remained

throughout, albeit a greater volume was consistently produced on the test

diets given the increased fibre content.

The first canine VFI study was undertaken in May 2014 and involved twelve

healthy neutered female adult small breed dogs (5 Miniature Schnauzers, 5

Bichon Frisés, 1 Miniature Dachshund and 1 Cairn terrier), in ideal body

condition (body condition score [BCS] 5/9), with a median age of 6y 8mo

(range 3y 10mo to 13y 0mo). The second canine VFI study was undertaken

in June 2014 and involved ten healthy beagle dogs (4 neutered females, 6

154 intact males) in ideal body condition (BCS 5/9), with a median age of 4y 3mo

155 (range 2y 8mo to 6y 0mo). The feline VFI study was undertaken in May 2014

156 and involved 12 healthy adult cats (7 neutered males and 5 neutered

157 females), with a median age of 4y 1mo (range 4y 0mo to 4y 3mo). Nine of the

158 cats were of the domestic shorthair breed, whilst the remaining 3 were

159 Bengal. Median body condition score was 4/9 (range 4-8/9), with 10 cats

160 being in ideal weight (BCS 4-5/9) and 2 cats being overweight (BCS 6/9 and

161 8/9).

162

163 The dog palatability study was undertaken in January 2014 and involved 37

164 healthy neutered female adult dogs (median age, 2y 10mo, range 1y 2mo to

165 11y 5mo) from various breeds including: Beauceron (1), Bernese Mountain

166 Dog (2), Brittany Spaniel (1), Cairn Terrier (2), Cocker Spaniel (4), Dachshund

167 (4), English Setter (2), Flat Coated Retriever (1), German Shepherd Dog (4),

168 German Wirehaired Pointer (2), Gordon Setter (2), Irish Setter (1), Jack

169 Russell Terrier (7), Miniature Schnauzer (1), Portuguese Podengo (1), and

170 West Highland White Terrier (2). The cat palatability study was undertaken in

171 July 2014 and involved 30 healthy adult cats (17 neutered females, 13

172 neutered males), with a median age of 7y 0mo (range 3y 4 mo to 14y 5 mo),

173 from various breeds including: Abyssinian (1), Bengal (2), Birman (4),

174 Chartreux (1), Domestic Shorthair (12), Exotic Shorthair (2), Maine Coon (2),

175 Oriental (1), Siamese (1), Somali (3), and Sphynx (1).

176

177 **Housing and husbandry**

178 Housing and treatment protocols adhered to European regulatory rules for

179 animal welfare. At site 1, dogs were housed in groups of two in closed indoor-

180 outdoor runs, the size of which varied depending upon the size of the dogs

181 (indoor box size: 5.4-9.3 m^2; outdoor run size: 3.6-12.5 m^2). For the feeding

182 studies, all dogs were fed individually, using separate 'traps' within their own

183 pen. At site 2, dogs were housed in groups of 6 in outdoor runs of 20 m^2, with

184 half of the run being covered. Dogs also had free access to dog houses of

185 1.9 m^2 (Dogloo® X-Large, Petmate, Arlington, USA). For the feeding studies,

186 dogs were again fed individually, this time using individual pens of 4 m^2. Cats

187 were group-housed in closed indoor-outdoor runs, of 27 m², with a maximum

188 of 8 cats per run. The runs with outdoor access were divided into an indoor

189 part (of 13 m²) and an outdoor part (of 14 m²). For the feeding studies, cats

190 were fed using automated feeding stations (see below). Dependent on the

191 season, the inside temperature varied between 18°C and 24°C. For both dog

192 and cat housing at site 1, artificial light was provided in addition to the natural

193 light, between 07.30 and 17.00, if natural light was judged to be insufficient by

194 the animal caregivers. This was not the case for site two because of the use

195 of outdoor runs. All dogs had exercise sessions of 2h/day at site 1 and at

196 least 1h/day at site 2. For cats, caregivers stimulated play behaviour for

197 approximately 2h per run, per day.

198

199 Diets

200 The VFI and palatability studies involved four complete and balanced diets,

201 purpose-formulated for weight loss, two designed for feeding to dogs, and two

202 for cats (Table 1). Diet C1 was a high protein high fibre diet (Satiety Weight

203   Management Canine, Royal Canin, Aimargues, France), whilst diet C2 was a

204   moderate protein high fibre diet (Prescription Diet® Canine Metabolic

205   Advanced Weight Solution, Hill's Pet Nutrition, Topeka, KS, USA). These two

206   diets differed in energy content (average dietary composition based upon

207   typical analysis: C1, 12041 KJ/kg [2876 kcal/kg]; C2, 12996 KJ/kg [3104

208   kcal/kg]) and macronutrient profile, with diet C1 containing more protein

209   (104g/1000kcal vs. 84g/1000kcal) and fibre (crude fibre: 58g/1000kcal vs.

210   43g/1000kcal), but less fat (33g/1000kcal vs. 37g/1000kcal) and nitrogen-free

211   extract (NFE 101g/1000kcal vs. 113g/1000kcal) than diet C2 (Table 1).

212

213   The ingredients used also varied, including fibre sources (C1: vegetable

214   fibres, beet pulp and psyllium [husks and seeds]; C2: pea bran meal, tomato

215   pomace, beet pulp, and powdered cellulose). The remaining two diets were

216   designed for feeding to cats (diet F1: Satiety Weight Management Feline,

217   Royal Canin Aimargues, France; Diet F2: Prescription Diet® Metabolic Feline,

218   Hill's Pet Nutrition Topeka, KS, USA). Protein content was similar between

219   diets (diet F1: 118g/1000kcal, diet F2: 121g/1000kcal), but diet F1 contained

220   more fibre (crude fibre: F1, 48g/1000kcal; F2, 29g/1000kcal; total dietary fibre:

221   F1, 82g/1000kcal; C2, 53g/1000kcal) and NFE (F1: 100g/1000kcal; F2:

222   93g/1000kcal), and less fat (31g/1000kcal vs. 41g/1000kcal), than diet F2.

223   Dietary energy content was also less in diet F1 (F1: 12405 KJ/kg [2963

224   kcal/kg]) than in diet F2: (14302 KJ/kg [3416 kcal/kg]). Again, ingredients

225   varied amongst diets, most notably for fibre source (F1: vegetable fibres,

226   chicory pulp, and psyllium [husks and seeds]; F2: powdered cellulose, tomato

227   pomace, and beet pulp).

228

229 Finally, organoleptic properties of the diets also varied amongst diets, with

230 differences including shape,colour, texture, and smell. Diets C1 and F1 had a

231 round (pastille) shape), whilst diets C2 and F2 had a triangular prism shape.

232 All diets were brown in colour, with the shade being marginally lighter for diets

233 C2 and F2 compared with diets C1 and F1, respectively. None of diets were

234 enriched with artificial colourings.

235

236 **Canine VFI studies**

237 Two studies were performed to determine VFI, with the first study using dogs

238 from site 1 and the second study using dogs from site 2. The design of each

239 study was the same, except that different methods were used for calculating

240 the metabolisable energy required for maintenance (MER; study 1: 110

241 Kcal/kg$^{0.75}$/day; study 2: 120 Kcal/kg$^{0.75}$/day), given differences in the known

242 MER of each group. In each study, dogs were fed the two diets (C1 and C2)

243 for a period of 7 days, using a crossover design (Figure 1), with half of the

244 dogs receiving diet C1 first, and the other half receiving diet C2 first. The

245 order of the diets was arbitraily decided in advance by the researchers, but

246 did not used a formal method of randomisation. In order to minimise

247 unwanted weight gain, the test protocol was performed on 3 non-consecutive

248 days for each study period whilst, on the non-study days, food intake was

249 reduced to 80% of MER (e.g. study 1: 88 Kcal/kg$^{0.75}$; study 2: 96 Kcal/kg$^{0.75}$).

250 The two periods ran consecutively, with no adaptation period between diets.

251 However, prior to the start of each study, all dogs had been offered both foods

252 to familiarise them. On test days, consumption kinetics was assessed

253 through repeated short-term food exposure, using a modification of a protocol

254 previously described [20,22]. Briefly, each dog was offered 110 kcal/kg$^{0.75}$ for

255 15 minutes at 08:30 (1st meal) and again at 09:30 (2nd meal), and then offered

256 food *ad libitum* for 15 minutes at both 10:30 (3rd meal) and 11:30 (4th meal).

257 At all meals, dogs left the bowl before the end of the 15-minute feeding

258 period, with most finishing eating within 5 minutes. Water was freely available

259 for consumption at all times. Food intake was measured by weighing the bowl

260 on calibrated electronic gram scales (Site 1: P8000-S, Mettler-Toledo,

261 Albstadt, Germany; Site 2: NVT 160 000, OHAUS, Nänikon, Switzerland; both

262 scales accurate to within 1g) before and after each meal to determine the

263 amount of food eaten.

264

265 Body weight (BW) was recorded on a weekly basis throughout the trial period

266 using calibrated electronic weigh scales (Site 1: SG16000, Mettler Toledo;

267 Site 2: SPIDER SW, Mettler Toledo, accurate to within 50g), and the mean

268 bodyweight for this period was used to calculate the mean study metabolic

269 body weight (MBW, e.g. BW$^{0.75}$ in kg; NRC 2006). Energy intake at each

270 meal was then calculated by multiplying the energy content of the food by the

271 amount consumed, and then dividing this by the dog's average study MBW.

272

273 **Feline VFI study**

274 As with the canine study, cats were fed the two diets (F1 and F2), each for

275 periods of 7 days, again using a crossover design (Figure 2), with half of the

276 cats receiving diet F1 first, and the other half receiving diet F2 first. Again, the

277 order of the diets was arbitrarily decided in advance by the researchers. Each

278 period consisted of an initial 2-day adaptation phase, and then a 5-day test

279 phase. On each test day, the respective diet was offered *ad libitum* for a

280 period of 18 hours, with no food being available for the remaining 6-hours so

281 as to limit excessive food consumption during the study. The period of food

282 availability (between 14:00 and 08:00 on each test day) was selected to

283 ensure that food was available for the known times of peak consumption

284 within the colony (i.e. during the evening and early hours of the morning), and

285 also fitted best with the daily routines of the animal caregivers. Water was

286 freely available for consumption throughout the study. Each cat had access

287 to its own food station by microchip recognition, and individual food intake (in

288 grams) was recorded daily using electronic weigh scales (M-Tronic Paris;

289 France; accurate to within 0.5 g). Energy intake was then calculated by

290 multiplying the energy content of the food by the amount consumed.

291

292 As with the canine study, body weight was recorded on a weekly basis

293 throughout the study period using calibrated weigh scales SG16000; Mettler

294 Toledo), and the mean body weight for the whole period used to calculate the

295 mean study MBW (e.g. $BW^{0.711}$ in kg; NRC 2006). Each cat's food energy

296 intake was then expressed relative to MBW.

297

298 **Canine and feline palatability studies**

299 For the canine palatability study, a panel of 37 entire female dogs

300 participated, all of which were routinely used in palatability testing at site 1. A

301 range of different sizes, breeds and ages were represented. The protocol

302 was repeated on 2 consecutive meals on the same day, at 08:00 and 16:00

303 (M1, M2). For each test, the two diets were served, side-by-side in identical

304 bowls, with the food allocated to each bowl arbitrarily decided. The amount

305 provided in each bowl was equivalent to twice the energy requirements

306 recommended for each dog. At the end of the 15-minute test period, the

307 amount of each food consumed by all dogs was measured.

308

309 A similar approach was chosen for the feline palatability study, although a

310 panel of 30 cats participated. Again, this panel was routinely used for

311 palatability testing, and a range of breeds, ages and genders was

312 represented. The protocol was performed twice on two consecutive days,

313 such that both diet (F1 vs. F2) and day (D1 vs. D2) effects were assessed.

314 As with the canine study, the two diets were served, side-by-side in two

315 identical bowls, with the food allocated to each bowl again arbitrarily

316 determined. The amount of each food provided was equivalent to twice the

317 energy requirements recommended for each cat. However, cats had free

318 access to both diets over a 22-hour-period (i.e. from 10:00 until 08:00). Food

319 intake of both diets was again recorded using the same approach as for the

320 canine palatability study.

321

322 **Data handling and statistical analysis**

323 The sample sizes decided for the studies were not determined by use of a

324 power analysis calculation. Instead, the group size used was equivalent to

325 that used in previous studies assessing VFI and palatability [20,22]. For the

326 VFI studies, the primary outcome measure of interest was the amount of

327 energy consumed (expressed both as KJ and Kcal per kg of MBW), whilst

328 secondary outcomes included the weight of food consumed (in grams), and

329 also BW (in kg) measured before and after each protocol (as described

330 above). For the palatability studies, the primary outcome measure was the

331 amount of each diet consumed in grams.

332

333 In all studies, complete data were available for all animals participating,

334 except for one cat in the Feline VFI study whereby malfunction of the

335 electronic food scales meant that the data could not be used. Data were

336 recorded in a computer spreadsheet (Additional file 1; Excel For Mac version

337 15.28, Microsoft Inc.) and analysed using the Statistical Analysis Systems

338 institute package (SAS version 9; SAS Institute Inc.). For the canine VFI, a

339 linear mixed model assessing the fixed effects of diet (C1, C2) and meal (M1,

340 M2, M3, M4), and their related interaction, on the food and energy intake of

341 dogs. The variable 'dog' was defined as a random term. In a similar manner,

342 a linear mixed model was used to assess the fixed effect of diet (F1, F2) on

343 the food and energy intake of cats, with the variable 'cat' being included as a

344 random term. Given the design of the palatability studies, the fixed effects of

345 diet (C1, C2 for dogs; F1, F2 for cats) and either meal (M1, M2) for dogs or

346 day (D1, D2) for cats with their related interaction were assessed on food

347 intake. The variables 'dog' and 'cat' were included as random terms in the

348 model.

349

350 In each case, when residuals of a model were not normally distributed at an

351 alpha risk level of 1% (Shapiro-Wilk and Kolmogorov-Smirnov tests), that

352 output variable was rank-transformed prior to analysis to be treated in a non-

353   parametric manner. Post-hoc analysis P-values were adjusted using Scheffe

354   method to deal with alpha risk inflation linked to multiple comparisons. Unless

355   indicated otherwise, all data are expressed as median (range). The level of

356   significance was set at 5% for 2-sided analyses.

357

Results

Canine VFI studies

Study 1

Before the study, BW was 5.82 kg (3.96-10.46 kg), and was 6.09 kg (4.00-11.44 kg), after the study. Despite the small but significant increase in bodyweight (+0.12 kg [+2.1%, of starting BW], range -0.10 to +0.98 kg [-2.4% to +10.3%], P=0.016), all dogs remained in ideal body condition (e.g. 5/9) throughout the study.

When food intake was assessed on an energy basis (Figure 2a), a significant diet effect was evident (P=0.032), with dogs consuming less of diet C1 (198 kcal/kg$^{0.75}$ [144-268 kcal/kg$^{0.75}$]) than of (C2: 206 kcal/kg$^{0.75}$ [121-338 kcal/kg$^{0.75}$]). Post-hoc analysis revealed the main difference in food intake to be at meal 2, where 42% less of C1 was eaten than C2 (P=0.006). . An interaction was also seen between the diet and meal effects (P<0.001), with the evolution of food intake over the successive meals differing between the two diets. Specifically, a significant reduction of energy intake was observed between the second and third meals for both diets (P<0.001), but between the first and second meals for diet C1 only (C1: P<0.001; C2: P=0.256). Nevertheless, an overall decrease in food intake between meal 1 and meal 4 was also evident for both diets (-86.5%, p<0.001; -88.1%, p<0.001 for diets C1 and C2, respectively).

When food intake was instead assessed on a gram weight basis (Figure 2b), the significant dog (P=0.016) and meal (P<0.001) effects remained, but there

383 was no longer a diet effect (total food intake on C1: 256g grams [150-542g];

384 total food intake on C2: 252g [113-476g]; P=0.964). However, the diet-meal

385 interaction was still evident (P<0.001) with a significant gram weight reduction

386 in food intake observed between the second and third meals for both diets

387 (P<0.001), but between the first and second meals for diet C1 only (C1:

388 P<0.001; C2: P=0.960).

389

390 *Study 2*

391 Before the study, BW was 11.54 kg (9.46-14.16 kg), 11.48 kg (9.60-14.28 kg)

392 after study period 1, and 11.34 kg (9.38-14.52 kg), after study period 2.

393 Bodyweight did not change significantly in this time (P=0.863), and all dogs

394 remained in ideal body condition (e.g. 5/9) throughout.

395

396 When food intake was assessed on an energy basis (Figure 3a), a significant

397 diet effect was again evident (P=0.019) with dogs consuming less of diet C1

398 (147 kcal/kg$^{0.75}$ [93-225 kcal/kg$^{0.75}$]) than of diet C2 (189 kcal/kg$^{0.75}$ [86-290

399 kcal/kg$^{0.75}$]; P=0.019). As with study 1, a significant meal effect was also

400 observed (P<0.001), with a significant reduction in intake occurring after each

401 consecutive meal, except between the 3rd and 4th meals. Finally, a significant

402 dog effect was also found (P=0.046), but there was no diet-meal interaction

403 (P=0.434).

404

405 When food intake was instead assessed on a gram weight basis (Figure 3b),

406 the significant meal effect remained (P<0.001), but neither the dog (P=0.052)

407 nor diet (total food intake on C1: 318g [202-487g]; total food intake on C2:

408 380g [173-582g]; P=0.255) effects were evident. In contrast to the results

409 expressed on an energy basis, a diet-meal interaction was evident (P=0.023;

410 diet C1: meal 1 vs. meal 2 P<0.001; meal 2 vs. meal 3, P=0.278; meal 3 vs.

411 meal 4, P=1.000; diet C2: meal 1 vs. meal 2 P=0.009; meal 2 vs. meal 3,

412 P=0.069; meal 3 vs. meal 4, P=1.000).

413

414

415 **Feline VFI study**

416 Prior to analysis, data from one cat were excluded on account of malfunction

417 of the electronic food scales. Body weight prior to and after the studies was

418 4.32 kg (2.66-5.88 kg) and 4.26 kg (2.67-5.81 kg), respectively. There was no

419 change in BW (P=0.067) over the study period, and there was no change in

420 BCS for any cat during this time.

421

422 During the course of the study, a diet effect was found when data were

423 expressed on an energy basis (P<0.001), with intake on diet F1 (55

424 Kcal/kg$^{0.711}$, 0-143 Kcal/kg$^{0.711}$) being 17% less than intake when consuming

425 diet F2 (66 Kcal/kg$^{0.711}$, 41-158 Kcal/kg$^{0.711}$). A significant cat effect was also

426 evident (P=0.023). When data were expressed on a gram weight basis, the

427 cat effect remained (P=0.023), but there was no longer a diet effect (F1: 51g

428 [0-127g]; F2: 55g [33-122g]; P=0.207).

429

430

431 **Palatability studies**

432 In the canine palatability test, the median intake of diets C1 and C2 was 41g

433 (range 0-350g) and 36g (range 0-350g), respectively. Total food intake

434 (combined intake of C1 and C2 for each dog) during the study was 136g (26-

435 427g). There was no significant meal effect (P=0.914) and no significant

436 difference in food consumption between diets was observed (P=0.490). In the

437 feline palatability test, the median intakes of diets F1 and F2 were 30g (0-66

438 g) and 7g (0-66g), respectively. Total food intake (combined intake of F1 and

439 F2 for each cat) was 40g (18-133g). No significant day effect was observed

440 (P=0.476), but there was a highly significant difference in consumption of the

441 two diets (P<0.001).

442

Discussion

In the current study, performance (in terms of VFI and palatability) of different commercially available purpose-formulated canine and feline weight loss diets was assessed in groups of healthy dogs and cats in ideal body condition. There were significant differences in overall energy intake between the diets tested in both the canine and feline studies. These findings are important given that maximising satiety is a critical factor for any diet used in a controlled weight loss programme [16,17].

The canine diets differed in energy content, macronutrient content, the sources of fibre, individual ingredients, and also in organoleptic properties. As a result, there could be various explanations for the observed differences. First, and most likely, the differences in energy intake could be due to differences in energy content because diet C1 was 8% less energy dense than diet C2. This explanation is supported by the fact that, when VFI was expressed on a gram weight basis (rather than on an energy basis), the diet effect was no longer evident. Against this, however, a diet-meal interaction was also observed: whilst, intake for both diets tended to decrease steadily across the four meals, differences in the pattern between diets was observed, most notably with a lower intake on diet C1 at meal 2. It is difficult to reconcile such a meal effect if the energy intake difference was simply due to relative energy dilution. Further, in a previous study with a similar design, the diet that was consumed least did not have the lowest energy content [22]. This suggests that factors in addition to energy dilution might be responsible for the observed differences in energy intake on the two diets. Other possible

468 reasons could include differences in macronutrient content, specifically protein

469 and fibre content, as previously demonstrated [17,22]. Relative to energy

470 content, diet C1 had 19% more protein and 21% more fibre than diet C2,

471 which is equivalent to the differences between the 3 diets used in a previous

472 study [22]. This again suggests that foods containing more protein and fibre

473 have the best satiety, an observation supported by human studies [26-30].

474

475 As for the canine studies, no differences in VFI were seen between feline

476 diets when measured by the gram weight, but cats consumed 17% less, of

477 diet F1 compared with diet F2, when intake was expressed on an energy

478 basis. Like the canine diets, the feline diets differed in energy (F1 15% less

479 than F2) and total dietary fibre content (F1 35% more than F2). However, in

480 contrast to the canine diets, protein content was similar between the feline

481 diets, and diet F1 also contained 32% less dietary fat than F2. Finally, there

482 were also differences in the type of fibre included and the ingredient lists for

483 the two diets. Whatever the reason for the diet effect on voluntary energy

484 intake, the results do suggest differences in the satiety effect between weight

485 loss diets in cats, supporting the findings of other studies whereby the same

486 diet resulted in less marked begging behaviour than other diets in obese cats

487 during weight loss [16].

488

489 With regard to fibre type, the main fibre sources in the canine and feline diets

490 where energy intake was least were vegetable fibres, beet pulp, psyllium and

491 chicory pulp (F1 only), whilst the fibre used in the diets where energy intake

492 was greatest was pea bran meal, tomato pomace, beet pulp, and powdered

493 cellulose. Fibre types can differ greatly in their properties, leading to highly

494 variable influences on water binding, gastric emptying, and the viscosity of the

495 digesta, thus exerting different effects on VFI. Indeed, studies undertaken in

496 humans have shown that psyllium improves satiety [31-33]. For instance, the

497 vegetable fibre used in diet F1 contains cellulose with a high water binding

498 capacity, and this could help delay gastric emptying explaining the improved

499 satiety. More details about the exact fibre blends used for each diet might

500 have shed light on their specific properties. However, since the diets used are

501 sold commercially, such details constitute proprietary information and

502 therefore are not publicly available. Therefore, it was not possible to fully

503 assess the relative effects of fibre type and other factors (such as

504 macronutrient content and energy density), and this is acknowledged as a

505 study limitation. Nonetheless, the advantage of using commercially-available

506 diets was the fact that the results would be more directly relevant to clinical

507 practice.

508

509 One possible explanation for a difference in VFI between two diets, is if they

510 differ in palatability and, for this reason, food preference tests were also

511 performed. The palatability of the two canine diets was equivalent, whilst the

512 feline diet that was least consumed was found to be significantly more

513 palatable. In light of these findings, palatability differences amongst diets are

514 not likely to account for study results, and the effect of the F1 diet on VFI in

515 cats may well be even more pronounced given this superior palatability. In

516 contrast, no differences in palatability were seen between the two canine

517 diets, again suggesting that this is unlikely to be the reason for the differences

518 in VFI between diets C1 and C2. However, it should be noted that this

519 palatability study was conducted in Winter, whilst, all other studies (including

520 the feline palatability study) were conducted in spring-summer. It is unclear

521 whether this difference might have affected the results obtained.

522

523 Different designs were used to assess VFI in the canine and feline

524 experiments. Dogs can consume large amounts of food in a single sitting,

525 whilst cats prefer to consume food in multiple meals throughout the day, with

526 each meal being small [34]. For this reason, the canine experiments involved

527 assessing short-term VFI by monitoring food consumption kinetics in a 4-hour

528 period, based upon a design used in a previous study [22]. In contrast, daily

529 VFI was measured in cats using automated food stations, again, as previously

530 reported [23]. The use of such food stations, which recognised individual

531 cats, allowed individual cats to consume food in whatever meal pattern they

532 preferred during the study period, whilst ensuring that the amount consumed

533 was accurately and precisely measured. In the authors' opinion, the use of

534 such devices is essential for assessing VFI in this species, and would

535 recommend them for all future studies.

536

537 As with any study, a number of limitations must be considered in addition to

538 those detailed above. First, studies used small groups of dogs and cats

539 housed in colonies rather than pet dogs and cats in their home environment.

540 Thus, results might not be generalisable to the larger pet population that

541 would have greater inherent variability in terms of animal factors, environment

542 and the fact that they would be client-owned. That said, the advantage of

543 using colony animals was the fact that experimental conditions could be better

544 controlled and study parameters such as food intake and palatability more

545 precisely measured. Second, the replicate experiments for the canine VFI

546 study were undertaken at different sites, using different dogs and housing

547 conditions. Although the results were broadly similar, there was some

548 variability observed. Third, also for the canine VFI studies, no adaptation

549 period was included between the test periods for each. This might have

550 affected the feeding kinetics of the study, although it is unclear as to whether

551 any systematic bias resulted because the order in which diets were fed was

552 arbitrarily decided.

553

554 A fourth study limitation was the fact that all of the VFI studies were short term

555 in nature, and it is not known whether the satiating effect wanes when a

556 restricted diet is fed continually. Similarly, the palatability studies were only

557 conducted over two consecutive meal periods (two meals in a single day for

558 dogs; two 22-hours periods on consecutive days for cats), and thus did not

559 assess whether taste preferences might have changed with time.

560

561 Finally, the study did not assess diet performance in overweight pet dogs and

562 cats during energy restriction in order to induce controlled weight loss;

563 instead, healthy research colony animals in optimal body condition were used

564 and none of them lost weight during the study. Therefore, the results of the

565 current study may not be generalisable to the target population. The main

566 reason for our choice of research colony animals over pet animals was a far

567 greater ability to control experimental conditions, thus improving accuracy of

568 results and reducing the number of animals required to participate. Whilst not

569 impossible, it would have been logistically difficult to perform similar studies in

570 overweight pet dogs in their own homes. In this respect, the study population

571 would inevitably have been far more variable, for example differing in the

572 degree of obesity, energy restriction required for weight loss, and in terms of

573 concurrent illness present [19]. There would also have been more variability

574 in housing conditions with differences in ambient temperature, lighting, and

575 space available. Husbandry practices would have differed markedly for

576 example the timing and method of feeding, provision of water, the exercise

577 undertaken, and also participation in play activity. Owner factors would also

578 be a consideration, with concerns over compliance with the study protocol

579 [14,15,18]. Moreover, there would likely have variability in experimental

580 conduct when extrapolated to the home environment and a greater likelihood

581 of errors made in the timing of meals and measurement of food consumption.

582 Finally, the use pet animals would have introduced ethical considerations;

583 although none of the procedures were invasive adverse effects making

584 adverse effects on welfare unlikely, it is questionable as to whether the

585 animals would have benefitted from participating in the study. All-in-all,

586 therefore, despite the inevitable limitations of using healthy colony animals,

587 this approach was preferred. Whilst caution should be exercised when

588 generalising our results to the wider pet population, the results are

589 nevertheless interesting, suggesting that diets C1 and F1 would perform

590 better and reduce unwanted begging activity in pets animals, as seen in a

591 previous field study [16]. Nonetheless, further studies would now be needed

592   in order to assess these diets under field conditions in obese dogs and cats

593   undergoing controlled weight loss.

594

595   **Conclusion**

596   In summary, the results of the experiments in the current study have

597   demonstrated differences in voluntary energy intake in both cats and dogs

598   when consuming commercially available weight loss diets. Possible

599   explanations for the superior performance of diet C1 (vs. diet C2) include

600   decreased energy content, increased protein and fibre content, and/or using

601   psyllium and beet pulp as the fibre sources. In contrast, the possible

602   explanations for the superior effect of diet F1 (vs. diet F2) include decreased

603   energy and fat content, increased dietary fibre content, and/or using psyllium

604   and chicory pulp as the main fibre sources. Further studies are now

605   recommended so as to assess the performance of these weight loss diets in

606   obese pet dogs and cats during a controlled weight loss programme.

607

Abbreviations

608

609 BCS   Body condition score

610 BW   Body weight

611 ONIRIS   Nutrition and Endocrinology Unit, National Veterinary School of

612   Nantes

613 MBW   Metabolic body weight

614 MER   Metabolisable energy required for maintenance

615 NFE   Nitrogen-free extract

616 SAS   Statistical Analysis Systems

617 VFI   Voluntary food intake

618

619

Declarations

620

Ethical approval and consent to participate

621

622 All experimental protocols complied with European Union guidelines on

623 animal welfare and were approved by the Royal Canin Committee for Animal

624 Ethics and Welfare. Since all studies were undertaken in research colony

625 animals from the institutions of the authors, no informed consent was required

626 from owners.

627

Consent to publish

628

629 Not applicable.

630

Availability of data

631

632 All data generated or analysed during this study are included in this published

633 article, and its supplementary information files (Additional file 1).

634

Competing interests

636 The diets tested were commercially available; Royal Canin manufactures two

637 of the diets studied (one cat and one dog), which were compared with two

638 diets (one cat and one dog) manufactured by a competitor. All but one of the

639 authors (Hours, Sagols, Junien-Castagna, Feugier, Moniot, Daniel, Biourge,

640 Serisier, Queau) are current or past employees of this company. The

641 remaining author (Alex German) is an employee of the University of Liverpool,

642 but his post is financially supported by Royal Canin. All the authors were

643 involved in the study design, in the collection, analysis and interpretation of

644 data, in the writing of the manuscript, and in the decision to submit the

645 manuscript for publication.

646

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649

Authors' contributions

651 M.A.H.   Designed the study, analysed the results, reviewed the manuscript.

652 E.S.. Designed the study, collected data.

653 A.J.-C.. Designed the study, collected data.

654 A.F. Designed the study, analysed the data.

655 D.M.. Designed the study, reviewed the manuscript

656 I.D. Designed the study, reviewed the manuscript

657 V.B.. Reviewed the study results. Reviewed the manuscript

658 S.S.. Discussed clinical data, reviewed the manuscript.

659 Y.Q. Contributed to discussions on study design, reviewed the manuscript

660 A.J.G. Reviewed the study results, wrote the initial draft of the manuscript.

661

662 All authors have approved the final article.

663

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669

References

1. Kealy RD, Lawler DF, Ballam JM, Mantz SL, Biery DN, Greeley EH. Effects of diet restriction on life span and age-related changes in dogs. J Am Vet Med Assoc. 2002;220:1315–1320.

2. Lund EM, Armstrong PJ, Kirk CA, Klausner JS. Prevalence and risk factors for obesity in adult dogs from private US veterinary practices. Int J Appl Res Vet Med. 2006;4:177–186.

3. German AJ, Ryan VH, German AC, Wood IS, Trayhurn PJ. Obesity, its associated disorders and the role of inflammatory adipokines in companion animals. Vet J. 2010;185:4-9.

4. Mosing M, German AJ, Holden SL, MacFarlane P, Biourge V, Morris PJ, Iff I. Oxygenation and ventilation characteristics in obese sedated dogs before and after weight loss: A clinical trial. Vet J. 2013;198:367-371.

5. German AJ, Holden SL, Wiseman-Orr, ML, Reid J, Nolan AM, Biourge V, Morris PJ, Scott EM. Quality of life is reduced in obese dogs but improves after successful weight loss. Vet J. 2012;192:428-434.

6. Marshall WG, Hazelwinkel HAW, Mullen D, De Meyer G, Baert K, Carmichael S. The effect of weight loss on lameness in obese dogs with osteoarthritis. Vet Res Comm. 2010;34:241–253.

695

696   7. Tvarijonaviciute A, Ceron JJ, Holden SL, Morris PJ, Biourge V, German AJ.

697   Obesity-related metabolic dysfunction in dogs: a comparison with human

698   metabolic syndrome. BMC Vet Res. 2012;8:147

699

700   8. Tvarijonaviciute A, Ceron JJ, Holden SL, Morris PJ, Biourge V, German AJ.

701   Effect of Weight Loss in Obese Dogs on Indicators of Renal Function or

702   Disease. J Vet Intern Med. 2013;27:31-38.

703

704   9. Laflamme DP, Kuhlman G. The effect of weight-loss regimen on

705   subsequent weight maintenance in dogs. Nutr Res. 1995;15:1019–1028.

706

707   10. Borne AT, Wolfsheimer KJ, Truett AA, Kiene J, Wojciechowski T,

708   Davenport DJ, Ford RB, West DB. Differential metabolic effects of energy

709   restriction in dogs using diets varying in fat and fiber content. Obesity Res.

710   1996;4:337–345.

711

712   11. Diez M, Nguyen P, Jeusette I, Devois C, Istasse L, Biourge VI. Weight

713   loss in obese dogs: Evaluation of a high-protein, low-carbohydrate diet. J

714   Nutr. 2002;132:1685S-1687S.

715

716   12. Nguyen P, Leray V, Dumon H, Martin L, Siliart B, Diez M, Biourge V. High

717   protein intake affects lean body mass but not energy expenditure in non-

718   obese neutered cats. J Nutr. 2004;134:2084S-2086S.

719

720 13. Laflamme DP, Hannah SS. Increased dietary protein promotes fat loss

721 and reduces loss of lean body mass during weight loss in cats. Int J Appl Res

722 Vet Med. 2005;3:62-68.

723

724 14. German AJ, Holden SL, Bissot T, Hackett RM, Biourge V. Dietary energy

725 restriction and successful weight loss in obese client-owned dogs. J Vet Intern

726 Med. 2007;21:1174-1180.

727

728 15. German AJ, Holden S, Bissot T, Morris PJ, Biourge V. Changes in body

729 composition during weight loss in obese client-owned cats: loss of lean tissue

730 mass correlates with overall percentage of weight lost. J Fel Med Surg.

731 2008;10:452-459.

732

733 16. Bissot T, Servet E, Vidal S, Deboise M, Sergheraert R, Egron G,

734 Hugonnard M, Heath SE, Biourge V, German AJ. Novel dietary strategies

735 can improve the outcome of weight loss programmes in obese client-owned

736 cats. J Fel Med Surg. 2010;12:104-112.

737

738 17. German AJ, Holden SL, Bissot T, Morris PJ, Biourge V. A high-protein

739 high-fibre diet improves weight loss in obese dogs. Vet J. 2010;183:294–297.

740

741 18. German AJ, Titcombe J, Holden SL, Queau Y, Morris PJ, Biourge V. A

742 cohort study of the success of controlled weight loss programs for obese

743 dogs. J Vet Intern Med. 2015; doi: 10.1111/jvim.13629.

744 19. German AJ, Andrews A, Holden SL, Morris PJ, Biourge V. Does

745 concurrent disease influence the success of weight management in obese

746 dogs? 57th British Small Animal Veterinary Association Congress,

747 Birmingham, UK; April 2014.

748

749 20. Serisier S., Pizzagalli A., Leclerc, L., Feugier, A., Nguyen, P., Biourge, V.,

750 German, A.J. Increasing volume of food by incorporating air reduces energy

751 intake. J Nutr Sci. 2014; 3: e59.

752

753 21. Alexander JE, Colyer A, Morris PJ. The effect of reducing dietary energy

754 density via the addition of water to a dry diet, on body weight, energy intake

755 and physical activity in adult neutered cats. J Nutr Sci. 2014;3:e21.

756

757 22. Weber M, Bissot T, Servet E, Sergheraert R, Biourge V, German AJ. A

758 high-protein, high-fiber diet designed for weight loss improves satiety in dogs.

759 J Vet Intern Med 2007;21:1203-1208.

760

761 23. Servet E, Soulard Y, Venet C, Biourge V, German AJ. Ability of diets to

762 generate 'satiety' in cats. [abstract]. J Vet Int Med. 2008; 22: 1482.

763

764 24. Floerchinger, AM, Jackson MI, Jewell DE, MacLeay JM, Hahn KA,

765 Paetau-Robinson I. Effect of feeding a weight loss food beyond a caloric

766 restriction period on body composition and resistance to weight gain in cats. J

767 Am Vet Med Assoc. 2015;247:365–374.

768

769 25. Floerchinger AM, Jackson MI, Jewell DE, MacLeay JM, Hahn KA, Paetau-

770 Robinson I. Effect of feeding a weight loss food beyond a caloric restriction

771 period on body composition and resistance to weight gain in dogs. J Am Vet

772 Med Assoc. 2015;247:375–384.

773

774 26. Blundell JE, Burley VJ. Satiation, satiety and the action of fibre on food

775 intake. Int J Obes. 1987;11 Suppl 1:9-25.

776

777 27. Stubbs RJ. Macronutrient effects on appetite. Int J Obes Relat Metab

778 Disord. 1995;19(Suppl):S11-9.

779

780 28. Louis-Sylvestre J. Toutes les protéines ont-elles le même pouvoir

781 satiétogène? Cah Nutr Diet. 2002;37:313-21.

782

783 29. Gerstein DE, Woodward-Lopez G, Evans AE, Kelsey K, Drewnowski A.

784 Clarifying concepts about macronutrients' effects on satiation and satiety. J

785 Am Diet Assoc. 2004;104:1151-3.

786

787 30. Bowen J, Noakes M, Clifton PM. Effect of calcium and dairy foods in high

788 protein, energy-restricted diets on weight loss and metabolic parameters in

789 overweight adults. Int J Obes. 2005;29:957-65.

790

791   31. Bergmann JF, Chassany O, Petit A, Triki R, Caulin C, Segrestaa JM.

792   Correlation between echographic gastric emptying and appetite: influence of

793   psyllium. Gut. 1992;33:1042-3.

794

795   32. Turnbull WH, Thomas HG. The effect of a plantago ovata seed containing

796   preparation on appetite variables, nutrient and energy intake. Int J Obes Relat

797   Metab Disord. 1995;19:338-42.

798

799   33. Rigaud D, Paycha F, Meulemans A, Merrouche M, Mignon M. Effect of

800   psyllium on gastric emptying, hunger feeling and food intake in normal

801   volunteers: a double blind study. Eur J Clin Nutr. 1998;52:239-45.

802

803   34. Ad Hoc Committee on Dog and Cat Nutrition, National Research Council.

804   Feeding behaviour of dogs and Cats. In: Nutrient Requirements of Dogs and

805   Cats. Washington DC: National Academies Press; 2006. p. 22-27.

806

Figure legends

Figure 1. Summary of the trial design for the voluntary food intake studies. For both canine studies, dogs were fed each diet, sequentially, for periods of 7 days. The test protocol (Test) was performed on 3 non-consecutive days for each study period, with food intake being limited to 80% of MER (e.g. study 1: 88 Kcal/kg$^{0.75}$; study 2: 96 Kcal/kg$^{0.75}$). For the feline voluntary food intake study, cats were fed each diet *ad libitium*, sequentially, for periods of 7 days, with each an initial 2-day adaptation phase (ADA) and then a 5-day test phase (Test).

Figure 2. Box and whisker plots of sequential energy (a) and gram weight (b) intake in the first canine voluntary food intake study (Study 1) where dogs were fed the two study diets (C1 and C2), over four meals. The boxes depict median (horizontal line) and inter-quartile range (top and bottom of box), the whiskers show the 10-90% range, and outliers are shown as separate points. Each dog was offered 110 kcal/kg$^{0.75}$ for 15 minutes at 08:30 (1st meal) and again at 09:30 (2nd meal), and then offered food *ad libitum* for 15 minutes at both 10:30 (3rd meal) and 11:30 (4th meal). (a) A significant reduction of energy intake was observed between the second and third meals for both diets ($P<0.001$), but between the first and second meals for diet C1 only (C1: $P<0.001$; C2: $P=0.256$). A diet effect was also evident ($P=0.032$), with the main difference being a lesser intake at meal two for C1 compared with C2 ($P=0.006$). (b) A significant reduction in gram weight intake of food was observed between the second and third meals for both diets ($P<0.001$), but

832 between the first and second meals for diet C1 only (C1: *P*<0.001; C2:

833 *P*=0.960). However, no difference in the gram weight intake of food was

834 observed between diets (*P*=0.964).

835

836 **Figure 3.** Box and whisker plots of sequential energy (a) and gram weight (b)

837 intake dogs in the second canine voluntary food intake study (Study 2) where

838 dogs were fed the two study diets (C1 and C2), over four meals. The boxes

839 depict median (horizontal line) and inter-quartile range (top and bottom of

840 box), the whiskers show the 10-90% range, and outliers are shown as

841 separate points. (a) A significant reduction of energy intake was observed

842 between the first and second (*P*<0.001) and the second and third (*P*<0.001)

843 meals for both diets, but there was no difference in intake between the 3rd and

844 4th meals (*P*=1.000). A diet effect was also evident (*P*=0.019), with the main

845 difference being a lesser intake at meal two for C1 compared with C2

846 (*P*=0.006). (b) A significant reduction in gram weight intake of food was

847 observed between the first and second meals for both diets (C1: *P*<0.001; C2:

848 *P*=0.009), but not between either the other meals. Further, no difference in

849 the gram weight intake of food was observed between diets (*P*=0.255).

850

Table 1. Average dietary composition based upon typical analysis of the 4 diets assessed used during the study

Criterion	Diet C1		Diet C2		Diet F1		Diet F2	
Species	Dog		Dog		Cat		Cat	
ME content[1]	12041 KJ/kg 2876 kcal/kg		12996 KJ/kg 3104 kcal/kg		12405 KJ/kg 2963 kcal/kg		14302 KJ/kg 3416 kcal/kg	
	Per 100g AF	g/1000kcal	Per 100g AF	g/1000kcal	Per 100g AF	g/1000kcal	Per 100g AF	g/1000kcal
Moisture	9.5	33	8.5	27	5.5	19	5.5	18
Protein	30	104	26	84	34	118	37.7	121
Fat	9.5	33	11.4	37	9	31	12.8	41
Crude fibre	16.6	58	13.4	43	13.9	48	9.1	29
TDF	28.1	98	23.8	77	23.6	82	16.6	53
NFE	29.1	101	35	113	28.8	100	28.8	93

Ash	5.3	18	5.7	18	8.8	31	6.1	20

| Ingredients | Vegetable Fibres, Dehydrated Poultry Protein, Wheat Gluten, Tapioca, Maize Gluten, Hydrolysed Animal Proteins, Maize, Wheat, Animal Fats, Beet Pulp, Fish Oil, Minerals, Fructo-Oligo-Saccharides, Soya Oil, Psyllium Husks and Seeds, Hydrolysed Crustaceans, Marigold Extract, Hydrolysed Cartilage; Vitamin A, Vitamin D3, E1 (Iron), E2 (Iodine), E4 (Copper), E5 (Manganese): E6 (Zinc), E8 (Selenium), Preservatives, Antioxidants | Chicken By-Product Meal, Whole Grain Wheat, Whole Grain Corn, Corn Gluten Meal, Pea Bran Meal, Soybean Meal, Soybean Mill Run, Dried Tomato Pomace, Chicken Liver Flavour, Dried Beet Pulp, Flaxseed, Coconut Oil, Pork Fat, Lactic Acid, Powdered Cellulose, Pork Liver Flavor, DL-Methionine, L-Lysine, Iodized Salt, Dried Carrots, Dicalcium Phosphate, Potassium Chloride, Vitamin E Supplement, L-Ascorbyl-2-Polyphosphate, Niacin Supplement, Thiamine Mononitrate, Vitamin A Supplement, Calcium Pantothenate, Biotin, Vitamin B12 Supplement, Pyridoxine Hydrochloride, Riboflavin Supplement, Folic Acid, Vitamin D3 Supplement, Lipoic Acid, Choline Chloride, Manganese Sulphate, Ferrous Sulphate, Zinc Oxide, Copper Sulphate, Calcium Iodate, Sodium Selenite, Taurine, Mixed Tocopherols, L-Carnitine, Beta-Carotene, Phosphoric Acid, Natural Flavours | Dehydrated Poultry Meat, Vegetable Fibres, Tapioca, Wheat Gluten, Wheat Flour, Maize Gluten, Hydrolysed Animal Proteins, Animal Fats, Minerals, Chicory Pulp, Fish Oil, Psyllium Husks and Seeds, Hydrolysed Crustaceans, Marigold Extract, Hydrolysed Cartilage, Vitamin A, Vitamin D3, E1 (Iron), E2 (Iodine), E4 (Copper), E5 (Manganese), E6 (Zinc), E8 (Selenium), Preservatives, Antioxidants | Chicken By-Product Meal, Brewers Rice, Corn Gluten Meal, Powdered Cellulose, Dried Tomato Pomace, Flaxseed, Dried Beet Pulp, Chicken Liver Flavor, Coconut Oil, Pork Fat, Lactic Acid, Potassium Chloride, Calcium Sulfate, L-Lysine, Choline Chloride, Carrots, DL-Methionine, Taurine, vitamins (Vitamin E Supplement, L-Ascorbyl-2-Polyphosphate (source of vitamin C), Niacin Supplement, Thiamine Mononitrate, Vitamin A Supplement, Calcium Pantothenate, Pyridoxine Hydrochloride, Riboflavin Supplement, Biotin, Vitamin B12 Supplement, Folic Acid, Vitamin D3 Supplement), minerals (Manganese Sulfate, Ferrous Sulfate, Zinc Oxide, Copper Sulfate, Calcium Iodate, Sodium Selenite), L-Carnitine, Mixed Tocopherols, Beta-Carotene, Phosphoric Acid, Natural Flavours |

[1] Metabolisable energy content for each diet was calculated using Modified Atwater factors, based on the declared average dietary

composition information for each diet. The effect of possible batch variation was not taken into account. AF: as fed; NFE: nitrogen

free extract; TDF: total dietary fibre. Diet C1: Satiety Weight Management Canine, Royal Canin, Aimargues, France; Diet C2:

Prescription Diet® Canine Metabolic Advanced Weight Solution, Hill's Pet Nutrition, Topeka, KS, USA; diet F1: Satiety Weight

Management Feline, Royal Canin, Aimargues, France; Diet F2: Prescription Diet® Metabolic Feline, Hill's Pet Nutrition, Topeka, KS,

USA.

Additional files

Additional file 1. Computer spreadsheet (Excel, Microsoft; .xlsx) containing data from all studies.

Figure 1