Evaluation of an Alternative Feline Diet at the Toronto Zoo

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INTRODUCTION

For many species of cats, little is known about their specific dietary needs. Although there have been some studies concerning digestibility and general nutrition of exotic cats species (Crissey *et al.* 1997; Allen *et al*. 1995; Wynne, 1989; Dierenfeld, 1987; Hackenburger and Atkinson, 1983; Barbiers *et al*. 1982), most information has been extrapolated from data concerning domestic cats (NRC, 1978).

With many cat species becoming endangered, stud books or species survival plans (SSP's) are being set up to advise on selected pairing as to ensure genetic diversity in the species. As this requires cats to be transferred to and from different institutions, the cat will be subjected to different diets, as few institutions currently used the same diet to feed their collection. It would be ideal if a nutritionally balanced, affordable diet could be produced and mass distributed to many zoos and game parks in order that the cats be fed the same diet.

The objective of this study was to investigate the feasibility of replacing the Toronto Zoo feline diet due to its high cost of production and/or develop an alternative feline diet that might be used by zoos. A commercial pet food manufacturer was retained to produce an alternative feline diet that could be packaged and sold to others zoos at a cost lower than currently required to produce a good quality feline meat diet. This diet was to be tested for both digestibility and palatability on cats at the Toronto Zoo.

MATERIALS AND METHODS

The study was conducted at the Toronto Zoo, Toronto, Ontario between November, 1995 and January 1996.

The study compared a meat-based diet currently used by the Toronto Zoo (TZ) against a new commercially prepared test diet. The control diet at the Toronto Zoo was the TZ feline diet, made of uncooked horsemeat with added supplements.

Animals used in the study included Sumatran tigers (*Panthera tigris sumatrae*), Snow leopards (*Panthera uncia*), Canadian lynx (*Felis lynx canadensis*), African cheetahs (*Acinonyx jubatus jubatus*) and African lions (*Panthera leo*). Sex and age of the animals are listed in Table 1. The animals were housed in their regular pens, which included access to interior and exterior areas. Animals were separated for feeding and fecal collection, otherwise may have access to common areas. Cats were randomly assigned to either a digestion trial or a palatability trial. The assigned trials are also listed in Table 1.

Table 1. Experimental Animals used in the study.

Species	Age (years; at time of study)
Digestibility Trial	
* 0.1 African lion "Natasha"	est. 21
0.1 African lion "Virginia"	est. 21
1.0 Snow leopard "Normandy"	2.5
0.1 Snow leopard "Juno"	2.5
1.0 African cheetah "Pete"	3.5
1.0 African cheetah "Bob"	3.5
Palatability Trial	
1.0 Sumatran tiger "Rengat"	3
1.0 Sumatran tiger "Rakata"	3
1.0 Snow leopard "Dimitri"	2.5
1.0 Canadian lynx	est. 16
0.1 Canadian lynx	est. 15

* male.female

Digestibility trial Three species of felines were selected for the digestibility trial. The animals were weighed and blood samples were taken immediately prior to the start of the trial. All items usually offered in addition to the meat diet, such as bones or whole animals, were removed for one week prior to and during the week of the digestibility trial. Therefore, during the first stage of the trial, the cats were fed only the control diet. Water was available ad. lib. for the duration of the trial. The digestion trial was run for seven consecutive days during which time the control diet offered was accurately weighed and recorded for each animal. The cats were fed at the same time each day (in the evening). Any refused food was collected and weighed. Fecal matter was collected the following morning, weighed accurately and stored at -20° C for future analysis.

After the seven-day digestibility trial of the control diet was complete, the additional items such as bones or whole animals were re-added to the diet. The test diet was then gradually introduced with the control diet by mixing different concentrations of the diets thoroughly in a Hobart mixer grinder (Model #4346). The introduction was to have been completed as follows:

Week 1 – 10:90 (test diet:control diet)
Week 2 – 30:70
Week 3 – 50:50
Week 4 – 75:25
Week 5 – 100% test diet

However, due to problems with the acceptance of the test diet, the introduction of the test diet was adjusted to the following schedule:

Week 1 – 10:90 (test diet:control diet)
Week 2 – 20:80
Week 3 – 30:70
Week 4 – 50:50

Week 5 – 75:25
Week 6 – 100 % test diet

At this point in the trial, the lions at the TZ were consuming 100% of the test diet and the digestibility trial for the lions was conducted over the next two weeks as described for the control diet. During the 7th and 8th weeks of the trial, while the lions' digestibility trial was being completed, Solka Floc ™, a commercially available fibre supplement and beet pulp were added to the test diet to improve the poor consistency observed in the diet.

In week 9, the manufacturer provided a new version of the test diet (Test 2) which was to have a better consistency than the first test diet (Test 1). The new test diet was added to the trail at an inclusion rate of 75%. By week 11 the cats were to be eating 100% Test 2 for the digestibility trial of this diet.

Due to problems with digestive upset or poor acceptance of Test 2, the digestibility trials of the test diet could not be completed at 100% test diet. The digestibility trial for cheetahs was conducted at a 50:50 ratio (test diet:control diet), while the digestibility trial for snow leopards was conducted at 75:25. The same protocol was followed as for the digestibility trial of the control diet. Following the digestibility trial, the cats were re-weighed, blood samples taken, and gradually returned to the control diet.

Fecal samples from all diets (within treatment) were pooled for each animal. The collected samples from each trial stage were mixed in a Hobart mixer (Model # A-200 FT) to a uniform consistency, then samples were taken for analysis.

Palatability Trial Felines not involved in the digestibility trial were used to determine the palatability of the test diets. As with the digestibility trial, all food items except the meat diet were removed for one week prior to and the week of the trial. All food offered and refused was weighed accurately. Feces were collected and stored at -20° C for future analysis. These cats followed the same schedule of introduction as those on the digestibility trial. The palatability trial was conducted for Test 2 at 75 % test diet and 25 % control diet. The cats were then returned to the control diet.

All laboratory analyses were conducted by Labstat, Incorporated of Kitchener, Ontario, Canada. Diet samples were analyzed for gross energy, protein, fat, ash, acid detergent fibre (ADF), neutral detergent fibre (NDF), moisture, calcium, phosphorus and amino acid and fatty acids profiles. Fecal samples were analyzed for gross energy, protein, ash, ADF, NDF, moisture, calcium and phosphorus. Blood samples were tested for taurine levels.

RESULTS

Although statistical analyses were not performed, strong trends in the results were observed. Results of the trials indicated that the test diets were not a suitable alternative to the TZ meat diet. This is based primarily on the cats' acceptance of the diet. Only the 0.2 African lions were able to eat up to 100 % of the test diet. The diet consumed by

lions was the first test diet which had to be modified for the other test animals due to its poor consistency. None of the other cats in the study could or would eat the diet at high inclusion rates. Food was either refused or the cats experienced digestive upset. The lynx vomited the test diets repeatedly. Of more concern, however, was the diarrhea and loose stool exhibited by all other cats at the zoo. The cheetahs could not consume the test diet at an inclusion level greater than 50 %. The Sumatran tigers, snow leopards and lynx could not consume a greater inclusion percentage than 75 % test diet without experiencing severe loose stool or diarrhea.

Also of concern was the weight loss exhibited by the cats on the test diet. Table 2 shows the weight of some cats both before the study and after the study. The largest weight loss was observed with the lions, which lost over 18 % of their body weight during the course of this study.

Table 2. Weight of Animals Used in the Trials.

Animal/Species	Pre-Trial, kg	Post-Trial, kg
Natasha/Lion	148.0	121.0
Virginia/Lion	136.0	111.0
Pete/Cheetah	49.9	49.7
Bob/Cheetah	47.2	47.2

Some notable differences were also observed in the diet compositions (Table 3). Both test diets had lower protein levels than the control diet. The protein level of the Toronto Zoo diet was 58.61% compared to the 36.84 % and 43.22 % of Test 1 and Test 2, respectively. Both test diets had higher fat contents than the control diet. The gross energy value (kcal/g) of the TZ feline diet was lower than that for both test diets. The test diets had lower calcium to phosphorus ratios than the control diet. The control diet's ratio was close to 1.70 to 1 whereas the test diets were lower, closer to 1 to 1.

Table 3. Proximate Composition of Feline Diets (DMB).

Nutrient	TZ Feline	Test Diet 1	Test Diet 2
Protein, %	58.61	36.84	43.22
Fat, %	24.58	41.12	33.17
Ash, %	5.35	4.80	6.15
ADF, %	5.97	0.75	2.35
NDF, %	58.43	29.03	32.44
Gross Energy, kcal/g	5.02	5.86	6.66
Calcium, %	1.23	0.69	0.77
Phosphorus, %	0.72	0.72	0.73
Ca:P ratio	1.70	0.95	1.05
DM, %	33.44	29.18	23.39

Differences were observed in the amino acid profile of the diets (Table 4). **Figure 1** shows the differences in the values of arginine, tryptophan, methionine and cystine and taurine. Blood levels of taurine are displayed in Table 5.

Table 4. Amino Acid Profile of Control and Test Diets (% DM).

Amino Acid	TZ Feline	Test Diet 1	Test Diet 2
Alanine	3.370	2.426	3.027
Arginine	3.487	2.142	2.514
Aspartic Acid	4.279	3.855	3.587
Glutamic Acid	6.687	4.959	5.263
Glycine	3.263	3.540	4.070
Hydroxy proline	0.682	0.843	1.227
Proline	2.494	2.371	2.604
Isoleucine	2.207	1.203	1.325
Leucine	3.807	2.587	3.373
Lysine	5.439	2.296	2.783
Methionine	1.071	0.524	0.338
Cystine	0.379	0.069	0.094
Taurine	0.349	0.264	0.564
Tryptophan	0.607	0.401	0.496
Phenylalanine	2.204	1.528	1.710
Serine	2.057	1.532	1.967
Threonine	2.028	1.371	1.689
Tyrosine	1.648	1.004	1.146
Valine	2.569	1.765	2.168
Histidine	2.410	0.805	0.923

Table 5. Blood Taurine Levels.

Animal	Pre-trial *	Post-trial **
African lion "Natasha"	107	91
African lion "Virginia"	193	223
Snow leopard "Juno"	118	128
Snow leopard "Dimitri"	140	155
Deficiency***	<50	<200

* plasma taurine levels, μmol/L

** whole blood taurine levels, μmol/L

*** Douglass et al., 1991.

The fatty acid profile, expressed as percentage methyl esters, is shown in **Figure 2**. The most notable differences are observed in the values for palmitoleic acid, stearic acid, linoleic acid and linolenic acid. The test diet values are noticeably lower for palmitoleic, linoleic and linolenic acids. The test diet values for stearic acid however, were more than three times those in the control diet.

Digestibility Trial The digestibility coefficients for protein, gross energy (GE) and fat of the diets are provided in Table 6. The mean digestive coefficients of the test diets were

lower than the TZ feline diet for all nutrients tested. The mean digestibility for GE was 88.2 +/- 1.02% for TZ feline and 76.6 +/- 1.98% and 82.6 +/- 3.97% for test diets 1 and 2 respectively. The protein digestibility dropped from a mean of 94.3 +/- 1.24% for the TZ feline diet to 76.7 +/- 0.92% for Test 1 and only 58.98 +/- 18.21% for Test 2. Most notably lower are the digestive coefficients for the snow leopards, which dropped below 50% for both cats studied. Digestive coefficients for fat also decreased from a mean of 96.6 +/- 0.86% for the control diet to 84.2 +/- 0.35% and 91.4 +/- 5.90% for Test 1 and Test 2.

Palatability Trial Neither test diet was found to be palatable by cats at the Toronto Zoo as demonstrated by their refusal or inability to eat the test diet at high percentages of inclusion.

Table 6. Digestibility Coefficients of Diets Consumed by Felines at the Toronto Zoo.

	Gross Energy, %			Protein, %			Fat, %		
Feline	TZ feline	Test 1	Test 2	TZ feline	Test 1	Test 2	TZ feline	Test 1	Test 2
African lion “Natasha”	89.90	78.00	-	96.20	77.30	-	95.00	83.90	-
African lion “Virginia”	86.90	75.20	-	93.00	76.00	-	96.70	84.40	-
Snow leopard “Normandy”	88.10	-	78.80	93.50	-	39.50	96.70	-	74.30
Snow leopard “Juno”	88.80	-	82.90	93.90	-	45.50	97.10	-	81.90
African cheetah “Pete”	87.80	-	88.00	93.70	-	76.50	96.30	-	88.70
African cheetah “Bob”	87.90	-	80.70	95.40	-	70.40	97.50	-	80.70
Mean	88.20	76.60	82.60	94.30	76.70	58.98	96.60	84.20	81.40
S.D.	1.02	1.98	3.97	1.24	0.92	18.21	0.86	0.35	5.90

DISCUSSION

The ingredients of the diets may have influenced the cats' acceptance of the test diets. The control diet is based on uncooked horsemeat, whereas the test diets were made from cooked beef and beef by-products and rice flour. As cats are strict carnivores the presence of plant material in the form of rice flour may have affected the palatability.

The appearance and presentation of the test diets may also have been an issue in acceptance. Test 1 was reported by keepers to be quite runny and very sticky. The control diet on the other hand, is more formed and not sticky – more like chunks of meat as opposed to the stew-like consistency of Test 1. The second test diet, while less runny and sticky than Test 1, was reported to be quite smelly. It also had a different appearance, not so much meat-like as a gelled mass similar to some canned dog foods.

The loose stool and diarrhea observed in the cats could have been the result of many variables. The change from raw to cooked meat may have been a problem for some cats. The decreased digestibility of the test diets may also be responsible for the soft, runny fecal samples observed. Some cheetahs were reported, at times, to have stool that looked identical to the diet, as if it was passing through the digestive system untouched. Plant material in the test diets may also cause digestive upset as they are less digestible by cats. Uncooked starches are poorly digested and lactose can cause diarrhea by changing the population of gut microflora (Scott, 1968). An overload of poorly digestible carbohydrates, such as some of those found in plant material, can also affect cats by changing intestinal metabolism which may cause a change in stool consistency (Kienzle, 1994).

The weight loss exhibited by some of the cats in the study may have been due to a miscalculated value of the energy density of the test diets, as well as the effect of the decreased digestibility of the diets. The energy density values of the test diet provided by the manufacturer were much higher than those obtained through analysis of the diets. Prior to the start of the study, the amount of test diet to be fed was calculated based on the energy intake of the control diet. As the test diet had been reported to have a higher energy value, smaller amounts were calculated to be fed so as to provide the same energy intake. However, as it turned out that the energy values were not as high as expected, the energy intake was lower. The decreased digestibility of the test diets was also likely responsible for much of the weight loss observed. The digestion coefficients of Test Diet 1 were, on average, 11.6 +/- 1.98% lower than the TZ diet for Gross Energy, 17.6 +/- 0.92% lower for protein and 12.4 +/- 0.35% lower for fat. Compared to the TZ diet, the digestion coefficients of Test Diet 2 were 5.6 +/- 3.97% lower for Gross Energy, 35.32 +/- 18.21% lower for protein and 15.2 +/- 5.90% lower for fat. The smaller amounts of food that were offered based on the energy densities, combined with the lower digestion coefficients of the test diets are likely a major cause of the weight loss that was observed with many of the animals.

All diets met or exceeded the recommended levels for protein, fat and essential fatty acids (Dzanis, 1994). All diets also had calcium:phosphorus ratios that were within the recommended range for domestic cats (NRC, 1978; Dzanis, 1994).

However, as cats are strict carnivores, they have different requirements for certain nutrients than other members of the order Carnivora. Cats require higher amounts of sulfur containing amino acids such as methionine, cystine and taurine. Also required in higher quantities than other mammals is arginine (Ullrey, 1983). The control diets met the recommended intake of all amino acids (Dzanis, 1994). The test diets were deficient in amounts of methionine and cystine present. Cats are unique in many aspects of sulfur amino acid metabolism, requiring higher amounts of sulfur amino acids than other mammals (Dierenfeld, 1987). Methionine requirements in particular are higher for cats and represents the most limiting dietary amino acid (Dierenfeld, 1987). As both test diets did not meet the required amounts of methionine, this could be a possible reason for the decreased protein digestibility as the lower amount of methionine present would limit the digestibility of all other amino acids as well.

Also required by cats is a dietary supply of taurine (Schaeffer *et al*., 1989). All diets met the recommended quantities of taurine in the diet. Taurine levels before and after the study are provided in Table 5. Based on a deficiency of <50 μmol/L for plasma taurine levels and <200 μmol/L whole blood taurine levels (Douglass *et al*., 1991), none of the cats were deficient in taurine prior to the start of the study.

After the study, according to the levels set forth by Douglass *et al*. (1991), 3 of the 4 cats tested were deficient in taurine. Studies have been done comparing the requirements for inclusion of taurine in canned and dry diets (Douglass *et al*., 1991; Anantharaman-Barr *et al*., 1994; Backus *et al*., 1994). Results of these studies have shown that to maintain the same blood taurine levels, cats fed canned food require higher concentrations of taurine in the diet than those fed dry food (Earle and Smith, 1991). This increased requirement for taurine in canned diets may be due to a reduction in the bioavailability of taurine due to the processing of canned diets as well as increased excretion of tauroconjugated bile acids and an increase of taurine degradation by the intestinal flora in cats fed canned diets (Anantharaman-Barr *et al*., 1994). As the test diets are canned, these factors should be taken into consideration.

The high fat content of the test diets may have had an effect on their digestibility by the animals. Although cats are generally capable of utilizing large quantities of fat, up to two-thirds of the dry weight of the diet (Scott, 1968), the deficiency of methionine in the test diets may have reduced their ability to digest the fat. There may be an increased need for S-adenosylmethionine for methylation reactions involved in the synthesis of phospholipids necessary for fat absorption and transport, which would reflect an increased requirement for sulfur amino acids (Schaeffer *et al.* 1989). As the test diets were deficient in the sulfur amino acids methionine and cystine, as well as being high in fat, their digestibility may have been reduced.

Cats have lost normal capacity of essential fatty acid metabolism, and as far as EFA requirements are concerned, it is an obligate carnivore. Most mammalian species studied thus far have shown that linoleic acid is a required EFA. In most animals, linoleic acid would be converted to arachidonic acid via a pathway involving the delta 6 desaturase and thus arachidonic requirements could be met by linoleic acid. However, the cat has been found to lack enough delta 6 desaturase enzyme to synthesize arachidonic acid via this pathway (MacDonald *et al*, 1984). Therefore, in the cat, arachidonic acid, as well as linoleic acid must be present in the diet.

According to the dietary requirements for cat diets listed by Dzanis (1994), all diets tested meet the recommended intakes of linoleic and arachidonic acids (**fig.2**). However, it also possible that the dietary requirements for the EFA can be influenced by the other ingredients of the diet. Likewise, there are likely some fatty acid interactions and competition that will affect the absorption and digestion of fats.

Previous studies have shown that EFA deficiency can be induced by the inclusion of certain ingredients in the diet. MacDonald *et al*. (1984) state that hydrogenated coconut oil in a diet accentuates EFA deficiency in the rat. Other studies by the authors found that the inclusion of tuna oil in the diet of cats increases the requirement of arachidonic acid (MacDonald *et al*., 1984). As the exact ingredients of the test diet are unknown, it is possible that a fat source was added to increase palatability. However, it is possible that the added fat source also affected the distribution of fatty acids and may have inadvertently increased the EFA levels required in the diet to prevent deficiency in the cats.

Both Test 1 and Test 2 had much higher amounts of stearic acid than the control diet. This, coupled with the lower amounts of linoleic and linolenic acids present in the test diets, could be contributing factors to the lower digestion coefficients observed. Stearic acid is readily desaturated to oleic acid. There is existence of competitive reactions among synthesis of acids from the linoleic and oleic families (Brenner, 1974). It has also been shown that there exists an inhibitory effect of different fatty acids on the desatuation of other fatty acids, depending on the relative proportion of substrate fatty acids to microsomal enzymes available, type of binding lipid and position of reactions in the lipid as well as relative amount and affinities of the fatty acids for the desaturase and accepting lipid (Brenner, 1974). As oleic and linoleic acids are desaturated by the same enzymes and much higher amounts of oleic acid are present in the test diets, both from the diet and conversion from stearic acid, the linoleic and linolenic acids present in the diet may not be fully utilized. This may be causing a deficiency of essential fatty acids. Among the many signs of EFA deficiency is low feed efficiency (MacDonald *et al*, 1984).

The possible inclusion of an added source of fat and the subsequent ratios of fatty acids, in particular stearic and oleic acids to linoleic, linolenic and arachidonic acids, may be, in part, responsible for the lower digestion coefficients and digestive problems observed in the test diets by inducing a deficiency of essential fatty acids.

The digestion coefficients of the TZ feline diet are similar to digestion coefficients of other raw meat based diets found by other researchers. Crissey *et al*. (1997) found that the apparent digestibility for protein of a raw meat-based diet by sand cats was 92.4+/- 5.3%. Hackenburger and Atkinson (1983) had apparent protein digestion coefficient values of 96.0 +/- 3.2% for tigers. Barbiers et al (1982) had apparent protein digestibility for cats ranging from 83.1% for a lion to 89.7% for a cougar. Another study involving lions and tigers fed a meat-based diet provided apparent digestion coefficients for protein of 90.6%f or the tigers and 91.2% for the lions (Wittmeyer Mills, 1980). The apparent digestibility of the TZ feline diet is comparable at 94/3 +/- 1.24%. The protein digestibility values for both test diets are noticeably lower at 76.7 +/- 0.92% and 58.98 +/- 18.21% for Test 1 and Test 2 respectively. However, the lower protein digestibility values for the canned test diets do fall closer to values obtained in studies testing digestion coefficients of canned diets. Morris *et al* (1974) had protein digestibility values of a canned diet of 78.4 +/- 0.35% and Wynne (1989) had protein digestion coefficients of 79.2 +/- 3.5%.

Values for fat digestion coefficients were also similar to other studies testing raw meat based diets. TZ feline diet values for apparent digestibility of fat were 96.6 +/- 0.86%. Fat digestibility of lions and tigers on a meat-based diet was 98.3% and 98.9% respectively in a study by Wittmeyer Mills (1980). Hackenburger and Atkinson (1983) had values of 98.7 +/- 0.7% while Barbiers *et al*. (1982) had fat digestion coefficients ranging from 94.7% to 99.0%. Fat digestion coefficients of Test 1 and Test 2, 84.2 +/- 0.35% and 81.4 +/- 5.90% respectively, were lower than the values obtained from raw-meat based diets as well as being lower than the value of 91.5 +/- 0.9% for apparent fat digestibility of another prepared diet (Wynne, 1989).

Energy digestion coefficients for the raw meat-based diets were also similar among the different studies. Sand cats had energy digestion coefficients of 89.6 +/- 5.2% (Crissey *et al*, 1997), while tigers showed energy digestion coefficients of 95.8 +/- 3.2% (Hackenburger and Atkinson, 1983). TZ feline diet produced energy digestion coefficients of 88.2 +/- 1.02%. Wittmeyer Mills (1980) found energy values of 92.9% and 91.1% for tigers and lions. Barbiers *et al*. (1989) had energy digestion coefficients ranging from 86.1% to 93.4%. The energy digestibility of Test 1 and Test 2, at 76.6 +/- 1.98% and 82.6 +/- 3.97% respectively, were lower than all values found for raw meat-based diet fed to cats. Energy digestion coefficients were not available for other canned diets.

As digestibility values for canned diets available are lower than those present for raw-meat based diets, it is possible that the lower digestion coefficients may be due to the processing of the diet. The lower digestion coefficients may also be affected by the inclusion of some plant-based ingredients. The compositions of the test diets, most notably the high fat, low sulfur amino acids and different fatty acid profiles may also be responsible for the decreased digestibility.

CONCLUSION

Based on the decreased digestion coefficients of the test diets and inability or reluctance of the cats to consume them, the test diets in this study were not suitable for use as primary diets by exotic cats.

More studies are required to develop a diet that could be commercially prepared and distributed to zoos at a lower cost than present diets for their exotic cat collections, as a common diet would facilitate the integration of cats into new institutions. As more and more species are driven out of their natural habitats, it becomes more crucial that we can maintain healthy, well adjusted populations in captivity.

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Figure 1. Amino Acid Profiles of Feline Diets

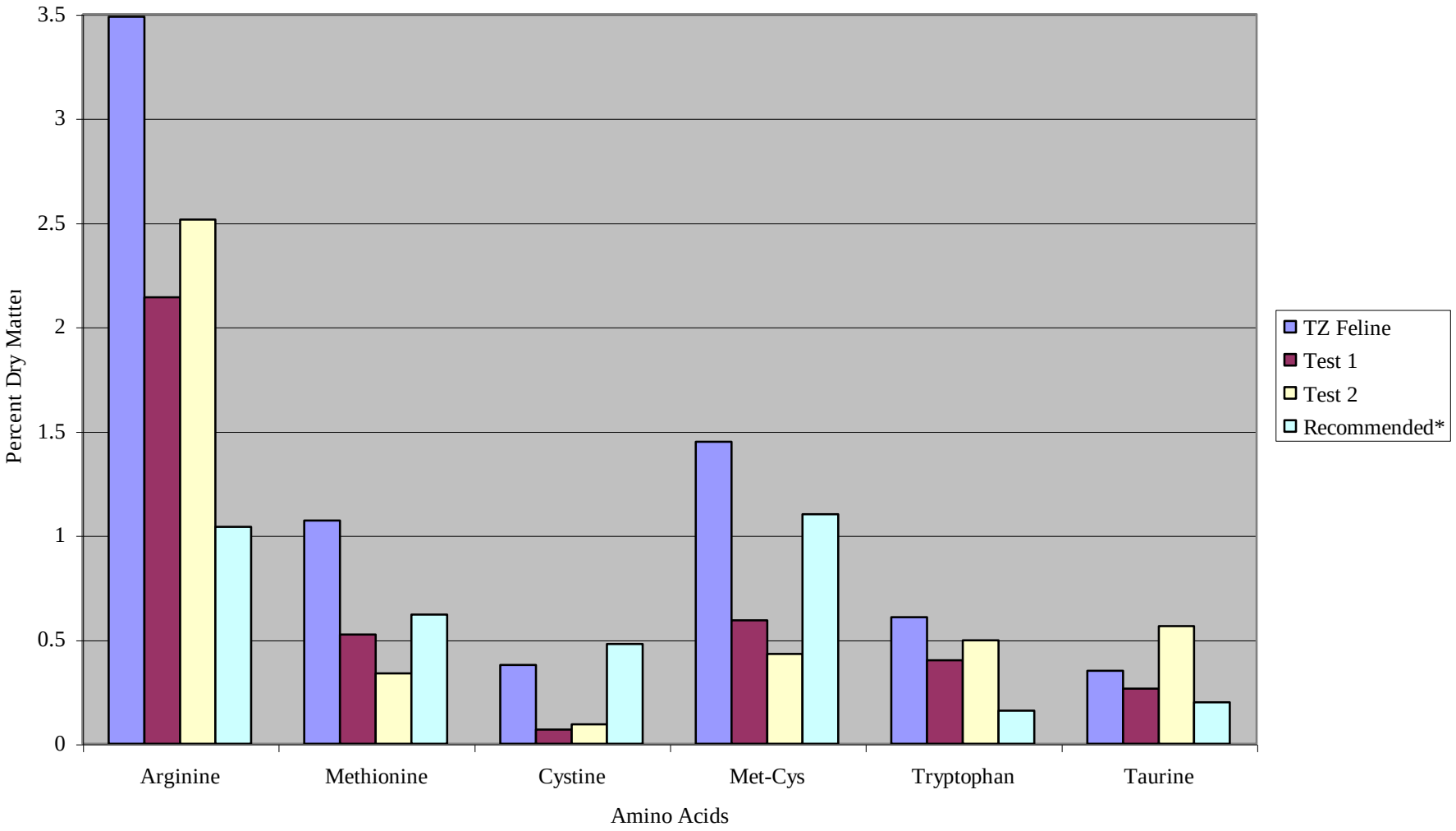
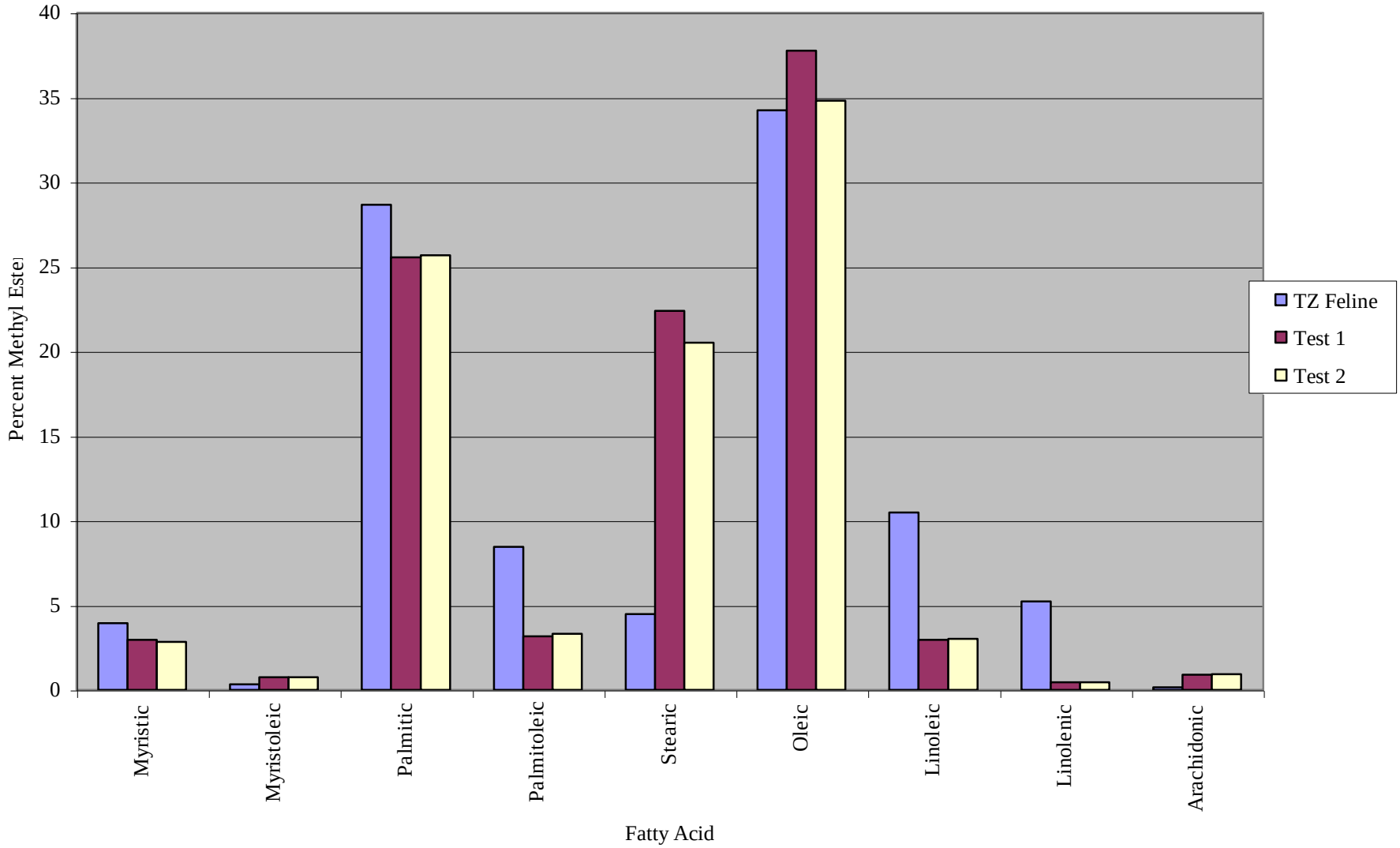


Figure 2. Fatty Acid Compositions of Feline Diets



* Dzanis,
1994

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