Monitoring Food Intake of a Pair of Major Mitchell's Cockatoos, (*Cacatua leadbeateri)*

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The food consumption of a pair of Major Mitchell's Cockatoos, *Cacatua leadbeateri,* (Leadbeater's or Pink Cockatoos) was monitored at the Metro Toronto Zoo (MTZ). The diet included a commercial pellet, MTZ "psittacine mix", mixed whole fruits and dried fruits and a seed mixture, the latter historically offered for behavioural enrichment. The diet had been offered to MTZ psittacines for several years but its acceptance by the cockatoos and therefore its nutritive value had not been evaluated in detail. The 21 day study was divided into three phases: Phase 1 where the diet was offered without the seed mixture, and all components of the diet were mixed together in one bowl; Phase 2 where the seed mix was excluded and components of the diet were offered in a partitioned food bowl; and Phase 3 where the seed mix was also offered to evaluate its effect on acceptance of the regular diet. Fresh and dry weights of offered and refused food were obtained. Nutrient content of the food intake in the three phases was estimated using a computer program and results from proximate analyses of the diet. The complete nutrient content of many of the items in the diet was unknown, particularly the vitamin content. General conclusions were drawn where data was complete in relation to requirements for the maintenance, and breeding/growing requirements for psittacines in the literature. The cockatoos consumed significantly less of the commercial pellets when seed was offered ($p = 0.01$). Crude protein levels in the diet were lower than optimum (18%) for breeding, especially if the seed is not included in the diet (where crude protein was 24%). The fat content in the diet was higher when seeds were consumed (5.7%) than when seeds were not present (5%). Requirements for breeding and growing were not met in levels of linoleic acid, arginine, lysine, methionine, threonine,(possibly cystine), sodium, potassium, manganese and copper. Levels were estimated to be deficient for maintenance requirements for sodium, potassium (where no seed is provided), manganese (when seed is provided) and possibly cystine. Alternate foods were discussed as well as the need to monitor the feeding preferences of individuals to ensure that a theoretically ideal diet is made a reality.

Key words: Cockatoos, *Cacatua leadbeateri,* feed intake, diet, captivity, nutrients

INTRODUCTION

The Major Mitchell's Cockatoo, *Cacatua leadbeateri,* also known as the Pink Cockatoo or Leadbeater's Cockatoo originates from the thick mallee scrub and arid country across much of Australia. Their distribution has been known to be of a "comparatively rare and thin sprinkling over a vast area" and of all the Cockatoos, has been one of two species needing serious protective efforts to preserve them from extinction (Eastman and Hunt, 1966). The International Species Identification System (ISIS) listed 123 Major Mitchell's Cockatoos in captivity in 1994, 42 males, 59 females and 22 juveniles (pers. comm.). At Metro Toronto Zoo (MTZ) a pair of these cockatoos was moved into a display in the Australasia pavilion in March 1994 in the hope that they would breed.

In general the zoo community still relies heavily on anecdotal information about the inhabitants' behaviour, physiology, and nutrition. It follows that there is a need for more reliable determination of the adequacy of diets of captive species. Nutrient requirements of birds can be considered according to their stage of life, activity (for instance nonbreeding adults), and reproductive status. The latter would include breeding birds, egg production and parental feeding (such as is the case with altricial species including psittacines) and finally the growing chick (Tollefson, 1982). The Major Mitchell's Cockatoo diet at the Metro Toronto Zoo was an example of a balanced diet being offered to a species where breeding was anticipated but where *the variability* in *actual* consumption of the food items was unknown, and lacking in a real nutritional assessment. The cockatoos had been provided with a diet which all psittacines at the zoo receive, a pelleted feed and a mix of soft foods prepared in the zoo's commissary. The diet is supplemented with fresh and dried fruits, vitamins and minerals and a seed mix is provided for behavioural enrichment. An evaluation was warranted particularly to determine any possible impact the seed mix would have on *nutrient* intake of the pair.

Individual birds will select specific food items often based on colour and texture rather than for the taste or nutrient content. Psittacines may become habituated or fixated on a specific item such as sunflower or safflower seeds and will not consume a balanced diet. Breaking this habituation and converting birds to a totally new balanced diet may take from weeks to months and is easier to accomplish in younger birds and smaller parrots (Kollias, 1995). Studies of caged psittacines have shown that the birds are not necessarily capable of making discriminating choices for their own best nutrition in captivity when offered cultivated seeds (Ullrey et al., 1991). *That* they show a preference for seeds does not mean this would be their only food choice in a natural habitat. In fact the misconception that psittacines are solely seed eaters or that seed diets offer complete nutrition is gradually being dispelled. Studies of wild psittacines demonstrate that their diets are often variable in the form the food takes (e.g. fruits, flowers, buds, leaves, cambium); there is a diversity in plant and sometimes insect species, the latter of which may be consumed deliberately or inadvertently in plant parts (Ullrey et al., 1991). Major Mitchell's Cockatoos are reported to feed on the seeds and bulbs of trees, plants and grass, and berries (Eastman and Hunt, 1966; 8oosey, 1956).

Seed mixtures have been replaced by extruded diets such as pellets, mash or crumbles in the poultry industry, and to a certain extent, in captive exotic animal husbandry. By meeting specific nutrient requirements of poultry, hatchability, chick viability, normal feathering and resistance to disease have all increased considerably (Ullrey et al., 1991). Care must be taken to ensure that pellets will be well received and that the birds can be trained to accept them. Even so, behavioural enrichment for many zoo animals is a growing concern and a necessary tool in captive animal welfare to avoid stereotypical behaviour. Given the intelligence of psittacines it follows that the potential for boredom is greater and that food is always an effective motivator, even if not the most creative approach. Therefore an ideal diet would include a pelleted diet in combination with other favourable and nutritionally valuable feeds. This practice however must be tailored to the individuals. Ullrey et al. (1991), found that when an extruded diet was offered with seeds, fruits and vegetables to three adult Timneh African Grey Parrots, seed consumption predominated. The diet was then marginal or deficient in methionine, calcium, available phosphorous, sodium, manganese, zinc, riboflavin, vitamin B12, available niacin, pantothenic acid, vitamin A and vitamin D.

Most commercially available seeds are deficient in certain limiting nutrients such as specific amino acids, vitamins, trace and macro minerals (e.g. calcium and phosphorous) (Kollias, 1995). This is especially true for the estimated requirements of growing altricial birds established by Ullrey et at. (1991) based on requirements estimated by the National Research Council (NRC, 1984). When eight seed types were evaluated for suitability, only three (peanuts, pumpkin/squash, sunflower), could provide enough protein for growth where the other types: corn, proso millet, oat groats, safflower, and wheat could not (Ullrey et al. 1991). Nutrient requirements for maintenance will be lower than those for breeding, and still lower than those for growing, but inadequacies of seeds can generally be applied to all categories. For reproduction certain seeds are still deficient in essential amino acids and most or all are marginal to deficient in calcium, available phosphorous, sodium, manganese, zinc, iron, iodine, selenium, vitamins A, D, E, K, riboflavin, pantothenic acid, available niacin, vitamin 812 and choline (Ullrey et al. 1991).

Estimated nutrient requirements for exotic animals must often be extracted from the requirements for domestic animals. More specifically, research on nutrient requirements of altricial birds has been limited, and Ullrey et al. (1991) provide nutrient specifications for an extruded diet as a complete diet for psittacines developed from the NRC recommendations and other researchers. They found that when eight psittacine species previously fed seeds, fruits and vegetables for two years, were fed an extrusion, fruit and vegetables but no seeds for one year, that fledgling percentage was greatly improved (90 vs. 66 %). The numbers of chicks hatched per year were not significantly different.

Brue (1994) provides nutrient allowances for companion bird diets as general dietary guidelines for most psittacines and the commonly kept passerines derived from Brue (1991) and the NRC (1984). It also includes the anticipated minimum requirements for comparison, extrapolated from other species. *The* values *they* list do not compensate for nutrient bioavailability, genetic variability and other conditions. It should also be noted that the recommended allowances they suggest will support normal maintenance of companion birds and have been shown to be suitable for long term feeding. The levels would not be adequate for breeding and growth which may require higher levels of the listed nutrients (Brue, 1994).

An ideal situation would be to provide a diet which would satiate the energy needs of the cockatoos according to the requirements of their stage of life, in combination with other nutrient needs and which could provide the requirements for a growing chick. This could start habituation to the *ideal* diet at an *early* age and ensure appropriate nutrition for future generations of breeding individuals. The present study was an attempt at a first step to establish how well the current diet is accepted by the cockatoos, including the influence of seeds present in the diet, and to make recommendations for ensuring adequate preventative nutrition.

METHODS

The food intake of a pair of Major Mitchell's Cockatoos *(Cacatua leadbeateri)* on exhibit at the Metro Toronto Zoo (MTZ) was monitored for a 21 day period in July and August, 1994. The pair consisted of a twenty year old male and a six year old female and had been housed as a pair for approximately seven months. Their weights were obtained on July 8, 1994 as the closest weights taken to the study period. The male weighed 400 g and the female weighed 350 g. Their weights

increased to 445g each in September, 1 994 and stabilized at 400 in December 1 994, and February 1995.

The diet for the cockatoos consisted of a daily ration of 80 g of MTZ "psittacine mix", which included MTZ carnivore vitamin supplement powder (Hoffman Laroche) and bone meal; 80 g of "Wings of Life" parrot maintenance pellets^{R} (Wings of Life); 10 g of bean sprouts; and 60 g of fresh and dried fruits offered three times a week. "Parrot Mix" (Elizabeth Feeds) was offered daily in 50 g amounts. The contents of the mixes and their proportions in the mixes offered are displayed in Table 1. Ten samples of each mix were sorted into their component parts and proportions were determined by weight. As per the original diet, oyster shell was available. The original diet also called for occasional cuttle bones.

The above ingredients approximated the usual diet offered to the cockatoos which also would include additional vitamin supplements usually added as per the keepers' routine three times a week; those being vitamin E supplement powder (Hoffman Laroche), Growmark vitamin supplement powder (Growmark), and MTZ carnivore vitamin supplement, each added into the previously mixed food. During the cockatoos usual routine, parrot mix was often added in variable quantities in the past, and either offered in the food bowl or scattered throughout the exhibit. Its original purpose was to provide behavioural enrichment for the birds. In the present study, the amount of parrot mix offered was standardized and placed in an adjacent food bowl to simulate its maximum availability in the past to the birds.

During the study period the food was offered between 8:00 and 9:00 a.m. and removed at 4:30 p.m. This was a routine established several weeks before the study period but in the past and at the present time the cockatoos have had variable access to their food overnight. The food was offered in one food bowl raised 1.5 m off the ground. A single feed station had been used for several weeks as the keepers had hoped this would help pair bonding. Observation had shown little to no competition for, or monopolization of, the food.

The study period was divided into three phases consisting of 7 days each. At the end of each day refused food was collected by the keepers from both the food bowl and an area under the food bowl and nearby perches of 2.1 m x 1.65 m collected on "indoor/outdoor" carpet. The cockatoos had been familiarized with the presence of the carpet for approximately 1 1/2 weeks prior to the study. A collection area of this size was deemed appropriate since the cockatoos had not been observed to take food items to other perches farther away from the food bowl perches.

In addition to the bird diet offered each day, a control diet of identical quantities was prepared to estimate water loss occurring throughout the day from any refused food collected. The control diet was kept in a holding next to the aviary and covered with a mesh screen to prevent vermin from eating any of the food. The holding approximated conditions in the aviary fairly well according to temperature conditions. Humidity and air exchange were not measured but were deemed to be fairly constant. The mean daily maximum temperature in the aviary was 25.1 °C and in the holding was 24.2 °C. The mean daily minimum temperature in both locations was 20.3 °c. The control diet was also spread onto a carpet section to undergo maximum water loss such as that undergone by scattered food remains. Samples collected at the end of each day were sealed in plastic bags and sorted into component parts and weighed the following day.

The food items offered in each of the three phases are presented in Table 2. Also presented here are the amounts of the food items offered and consumed per pair. Only in Phase 3 was the parrot mix offered in an attempt to establish what influence, if any, its presence had on consumption of the other items. Phase 1 presented some difficulty in sorting through food remains mixed in one bowl. Due to time constraints on sorting, it followed that Phase 2 involved the use of an identical stainless steel food bowl but with partitions soldered into it to form three components; psittacine mix, Wings of life, and mixed fruits were then offered in three discrete piles. Phase 2 did not commence until one week after Phase 1 to allow for the preparation of the bowl, and to enable several days for the birds to become accustomed to it. Phase 3 saw the Parrot mix added to the diet, offered in a separate bowl in an adjacent holder.

All weights of refused food were corrected for water loss based on the water lost from the control diet in order to best establish the weight of food consumed. Where mixes of food were involved, the ideal method of determining component consumption would have been to weigh separately each component being offered and the refusals sorted down into component parts. Time constraints did not allow for the former, but refusals were sorted into component parts as much as possible. The pellets and the psittacine mix were in part collected as crumbs. Where crumbs were too small to further sort through a sieve (in amounts of 4g to 11 g), the combined remains were assumed to be 50% of each. Other component parts found to be left over were subtracted from the average proportions determined for each particular component present in the mix. In this way, the assumption that all components are consumed equally was somewhat lessened. The amounts eaten per pair were thus established on an "as fed basis" .In order to approximate food intake per bird, the assumption was made that each ate an identical amount and that neither bird ate 100% of anyone item. The amount eaten per pair was divided into two for a "per bird" estimation.

Paired t tests were performed (Statistix 4.0, Analytical Software) on the mean amounts of psittacine mix and Wings of Life pellets eaten by the pair in each of the three phases. This was to determine if the amounts eaten in Phase 3 differed from those in phases 1 or 2, and if there was any significant difference between Phases 1 or 2.

Proximate analyses were performed on samples of Wings of Life pellets and psittacine mix (Crampton Nutrition Lab, McGi11 University, Quebec) for dry matter content, crude protein, crude fat, ash, acid detergent fiber, calcium and phophorous, and gross energy.

The mean amounts consumed of each food item per bird, on an as fed basis were analyzed using the Animal Nutritionist Computer Program (N-Squared Computing Software, 1991) and nutrient concentrations were calculated on a dry matter and as fed basis. Specific chemical information for the Wings of Life pellets was available arid was entered into the program. Specification data analysis of the dog food used in the psittacine mix was entered into the program (K-9 Selection, Maple Lodge Farms) but the dog kibble in the parrot mix was known to only be of "Purina" brand and so a Purina dog chow was chosen from the computer database and used in the analysis of parrot mix. The supplements used in the psittacine mix were present in the database and included in the analysis. Of the additional three vitamin supplements, two were present in the database (Vitamin E, MTZ carnivore supplement) and for the third (Growmark Vitamin Supplement), Hartz Vit-Min for Cockatiels was substituted. Information on dry matter concentration and as fed concentration amounts per feed was obtained.

In addition, estimates of metabolizable energy (ME) available in each feed (the diet) were presented by Animal Nutritionist (AN) using coefficients for energy obtained from the protein, fat and digestible carbohydrate portions of the diet. The digestible carbohydrate was unknown but was calculated from the following equation:

CH2O = dry matter -crude protein -fat -fiber -ash

where "fiber" was to represent the diet's indigestible fiber fraction for a particular animal. For the cockatoo diet, crude fiber was the only complete dataset of values for each food item and was therefore used as the indigestible fiber fraction. This however would overestimate the amount of energy in the diet being derived from carbohydrate.

As a comparison, another estimate of ME was calculated using the AN program. Metabolizable Energy for birds was derived from values for percent dry matter and gross energy (on an as fed basis) (source: Robbins, 1983). Therefore, for Phase 2 the values of total ME from the feed were derived from the gross energy of psittacine mix and Wings of Life pellets (values for beansprouts were unavailable). As the gross energy values for the two feed items was only available on a dry matter basis the estimate may be higher than the true ME content in the feed. For Phase 3 the ME/feed was obtained from the estimate obtained through the gross energy values of psittacine mix and Wings of Life pellets, plus the ME values for poultry of the Parrot Seed mix, available in the AN database. Both estimates of ME/feed are listed for phases 2 and 3 in Table 3. Animal Nutritionist^{R} also calculated an estimate of the Metabolizable Energy requirement for Psittacines based on the body weight of the cockatoos (0.34 kg).

Contact was made with five other North American zoos holding Major Mitchell's Cockatoos to gather information on other diets in captivity, and any information on weights or breeding success.

RESULTS

The results of monitoring the food intake of MTZ's pair of Major Mitchell's Cockatoos showed that all food mixes are sampled except the mixed fruits. Table 2 shows the food intake per pair in the three phases of the diet study. Fruit was sampled on one day only, in Phase 1 and that was only 4.8 g. This may even have been a result of one piece of fruit having not been recovered during the collection of refusals. Beansprouts was the only fresh or raw food item taken. There were highly variable ranges in the intake of psittacine mix in each of the three phases, consumption of Wings of Life pellets was also variable except in Phase 3 where the pellets were accepted in much smaller, less variable quantities (0.0 g- 9.2 g). parrot mix was steadily taken in Phase 3, apparently in lieu of the pellets. Beansprouts also were refused in Phase 3.

Performance of Paired t tests revealed no statistical significance between the pellets eaten in phases 1 and 2 ($p = 0.611$) or in the amounts of Psittacine Mix eaten in phases 1 and 2 ($p = 0.376$). Given that the only difference in phases 1 and 2 was the partitioned bowl, a t -test was performed for phases 2 and 3. There was no significant difference in the amounts of psittacine mix eaten in phases 2 and 3 ($p = 0.291$). However a statistically significant difference in the amount of pellets eaten by the birds ($p = 0.01$) was found between phases 2 and 3 of the trial. The pair ate a significantly lower amount of pellets when they had the option to eat a seed mix.

The Animal Nutritionist output on nutrient concentration on a dry matter and on an as fed basis per bird is shown in Tables 3 -6. In addition, the percent difference in nutrient concentration on an as fed basis between phases 2 and 3 is also shown. The values in Tables 5 and 6 are based on the diet without the three times weekly additional supplements, i.e. the minimum nutrients available. Values listed in brackets represent the nutrient amounts when those additional supplements are added. Any values in Tables 3 -6 where asterisks are shown, indicate that greater than 50 % of the values for that nutrient were not available in the database for the food items in the diet. Conclusions cannot be made that the table values are true values until a more complete dataset is established.

The estimated metabolizable energy available from the feeds of the three phases is shown in Table 3. The values were obtained from the metabolizable energy coefficients for the protein, fat and digestible carbohydrate portions of the diet show the energy level of Phase 1 to be the highest (97.61 kcal/total feed intake). The estimated ME was 256 kcal/100g of food for Phase 1 and 260 kcal/100g for Phase 2 (giving 86.97kcal/feed intake). Since the average amount of food eaten in Phase 1 was slightly higher (38.13g per bird) than in Phase 2 (33.45g per bird) this accounted for the higher energy. A more noticeable difference is the ME derived for Phase 3, 73.44 kcal per feed, derived from 25.86 g eaten of a feed yielding 284 kcal/100 ME. In Phase 3 the feed potentially yields more energy but less amounts were consumed.

The estimated energy requirement for maintenance for Psittacines of 350 g and 400 g was calculated by Animal Nutritionists to be 52.1 kcal/day and 57.0 kcal/day respectively (30°C, 15 hour photoperiod, Kendeigh et al., 1977). For the mean weight of cockatoos in the literature, 310 g, the estimated maintenance energy requirement would be 48.1 kcal/day (30°C, 15 hour photoperiod, Kendeigh et al., 1977).

The dry matter content is highest in Phase 3 (82.75), because of the seed portion consumed. The crude protein of the diet on a dry matter basis is similar in phases 1 and 2 (18%) but is 24% in phase 3. The Phase 3 feed is also higher on a dry matter basis in crude fiber (16.99%), ash (4.59%) and fat (5.7%). Without the parrot mix the crude fiber is approximately 14%, ash and fat are 5%.

The linoleic acid is 1 to 1 1/2% and lower in Phase 3, however attention must be drawn to the lack of a complete database, even so, the sources of linoleic acid are listed as dog chow, and pellets. Linoleic acid is higher in Phase 2 than in Phase 3 since pellets were consumed in higher amounts in phase 2.

Table 4 lists amino acid content in the diet. The asterisks indicate where less than 50% of *the* data on nutrient content of *the* food items is unknown. However , in regards to amino acids most of the data that are unknown are for the boiled vegetables present in the psittacine mix. Due to the shorter list of food items in Phase 2, "50%" of the data is missing compared to Phase 3 where data on all the seeds in the parrot mix are better known and therefore are greater than the "50%" minimum. The estimates for amino acids are probably not very different than true values. The increases observed in many of the amino acids in the Phase 3 feed are probably justified since not only are there amino acids from the seeds, there would be more in the dog kibble of the parrot

mix, but that information for amino acid content was not available in the database. Unfortunately values for cysteine were not available for either the dog chows or Wings of Life pellets so the increase represented in Phase 3 is based on seed data alone (0.0 -0.24%).

Table 5 lists the information available on dry concentration of vitamins. For all of the vitamins except vitamin A the data is unavailable on pellets and the dog chow in the psittacine mix. Therefore the vitamin information available for the parrot mix, kibble, and the seeds gives an untrue picture of true vitamin content. Judgment should be withheld until a more accurate database can be established. In regards to vitamin A, the dry matter concentration was higher in Phase 3 (10.59 IU/g) than in Phase 2 (9.33 IU/g). The Purina kibble in the parrot mix provides more vitamin A than the chow in the psittacine mix. These two items are also offered in different forms; the chow is presoaked in water in the psittacine mix while in the parrot mix, kibble is available in 1 cm square pieces. The present study showed that more soaked dog chow was estimated to have been eaten in the psittacine mix than in kibble in the parrot mix (Table 7). The amount of increase vitamin and mineral supplements raise nutrient intake is demonstrated well in Tables 5 and 6.

Vitamin E content in the diet is derived from a fairly complete database for all of the major food items in the diet; such as the supplement, the psittacine mix vegetables and dog chow, the parrot mix seeds and dog chow and the Wings of Life pellets. The dry matter concentration of vitamin E is higher in phases 1 and 2 (75 - 80mg/kg) but on an as fed basis vitamin E is 8% higher in Phase 3. The addition of supplemented vitamins results in a dry matter concentration of 445.7 mg/kg in Phase 2 and 337.1 mg/kg in phase 3.

Table 6 lists mineral content of the diet. The database is fairly complete across the major feed components in all phases. A cautionary note is again added here that while an addition of seed to the diet may show increases in mineral content, the vitamin and mineral supplements may compensate for minerals lacking without the seeds. This is the case for iron, zinc, copper, manganese and selenium which were all of higher concentrations if Phase 2 over Phase 3. In phases 1 and 2 the calcium:phosphorous ratio is 1.5: 1 but in Phase 3 it is 1: 1.2. Although the free choice oyster shell is not included here, the increased phosphorous from the seeds of the parrot mix had imbalanced the ratio. With the addition of supplements the ratio is better balanced. The lesser amounts of iron, zinc, copper and manganese in Phase 3 are probably accounted for because the pair ate less psittacine mix (less than 8.68 g including the dog chow and supplements therein) and less pellets. Higher iodine and cobalt was a result of incomplete databases for pellets, and the dog chow in the psittacine mix.

Contact was made with 5 zoos holding Major Mitchell's Cockatoos. Two of the five have bred their cockatoos, 2 have not yet and 1 has not bred them recently. All five institutions use either avian or primate pellet brands; some kind of supplement (3), no supplement (1) and one zoo where this information was unavailable; fruits and vegetables daily (3 zoos) or two times a week (2) or not at all (1). Included in the list of fruits and vegetables are apples, oranges, carrots, sweet potato or squash, cauliflower, broccoli, cantaloupe, watermelon. Only one institution uses a "diet seed mix" (safflower base) with commercial dry food and no vegetables, however when the cockatoos have chicks, bread is given with a calcium supplement. At this institution every second or third season they see a calcium deficiency in the chicks. Next year this institution will change

the diet to being pellet based. One other institution cited sunflower seeds and peanuts as occasional treats.

Body weight data were available from one institution where the male ranged from 335g to 386g and the female ranged from 335g to 369g.

Conclusions about breeding related to nutrition cannot be made here, management practices and pair dynamics were not investigated. Data on the birds' health as well as actual consumption of the above-mentioned diets were not established.

Food item preferences in each of the three phases were estimated for the pair of Major Mitchell's Cockatoos at MTZ based on the percent consumption of each item and listed in Table 7. In Phase 2 psittacine mix and Wings of Life pellets on the average were taken in roughly similar amounts (38- 39%). This percentage may be underestimating the cockatoos' acceptability since they are given liberal amounts (80 g each per pair). In Phase 3 the preference for the psittacine mix goes down to 29%, pellets down to 2% and there is a preference for parrot mix 48% (48% of 50g offered per pair). The proportion of component parts eaten in psittacine mix is an estimate based on the average proportions that those components were present in the mix. While the assumption was made that each component was taken equally, any recovered items were subtracted from the proportionate amount to lessen any error. The lack of variability in the percents of components consumed seems to indicate that there was not a noticeable preference for anyone item, especially in Phase 3. There was slightly more variability in seed types taken, evidenced by recovered seed hulls. Sunflower and safflower were well received, and oat groats, milo and kibble were moderately preferred. Buckwheat, kibble and corn were taken in lesser amounts.

DISCUSSION

The results of the present study showed that the pair of cockatoos consumed significantly more seed than pellets when offered a choice, and has been seen elsewhere in a study involving three adult Timneh African Gray Parrots (Ullrey et al. 1991). The cockatoos did continue to eat the MTZ psittacine mix though in somewhat smaller amounts. Whether the effect that the presence of seed mix seems to have on the consumption of pellets and psittacine mix is reversible or not is unclear. Seed mix was discontinued prior to the study but what that baseline consumption of pellets ever would be without seed mix having been recently offered is unestablished.

The nutrient analysis was incomplete for comment regarding all of the vitamins except vitamin A, E and D3. Values for amino acids except tryptophan, cysteine and taurine were estimated from fairly complete databases. The database for mineral content of the food items was also complete except for selenium, iodine and cobalt. The estimated nutrient requirements for breeding and growing psittacines derived by Ullrey et al. (1991) were used for comparison with nutrient levels in the analysis of the cockatoo diet. The estimates of recommended allowance for maintenance requirements of psittacines and passerines derived by Brue (1994) were used as the minimum levels of nutrients that should be present in the cockatoo diet.

The protein level in the MTZ cockatoo diet is the recommended level for breeding by Ullrey et al. (1991) in Phase 3 only, when the seed mix is consumed (24.01% dry matter). This value is derived from experiments by Roudybush and Grau (1986) which established that 20% protein

was the lowest concentration permitting maximal growth of hand fed cockatiel chicks. Chicks fed a 10% or 15% crude protein diet grew considerably slower (cited by Ullrey et al. 1991). Brue (1994) lists the recommended maintenance allowance to be 12.00%. The crude protein in Phase 2, the diet without seeds was 18.41 %. Ullrey et al. (1991) listed no nutrient specification for fat levels in a psittacine diet. The percent concentration of fat cited as a recommended allowance by Brue (1994) is 4.0%. The percent fat concentration was above this in phases 2 and 3. This fat level is probably too high given the weight gain observed in the cockatoos over several months. Ullrey et al. (1991) recommended a linoleic acid concentration of 2 g per 100g dry matter. In both phases of the diet study the linoleic acid is deficient for breeding and Brue (1994) states no recommended allowance.

The food consumption in Phase 2 yields metabolizable energy somewhere in the range of 86.97 kcal/feed intake (31.04g), a possible underestimate to 121.25 kcal/feed, a possible overestimate. With the addition of seed to the diet and the subsequent lack of consumption of pellets, the ME available decreases in the range of 73.44kcal/feed intake (26.03g) to 68.29 kcal/feed. Since the first value was believed to be a possible underestimate of ME available, it appears that it may be close to a true value since it is larger than 68.29 kcal/feed (presumed to be an overestimate). The estimated M E requirements based on body weights would have been 52.1 kcal/day (the female) to 57.0 kcal/day (the male). The food consumption in all of the phases appears to provide the required amount of ME. It appears more likely that the estimate of ME / feed is higher than the true requirement. The result of a higher fat diet is greater fat deposition as a bird eats to fulfill its energy requirements, as appears to be the case in early 1995 with the cockatoos. The energy requirements would be expected to increase approaching the breeding season, and with access to seeds the birds may continue to build up too much fat. It may be noted here that from February and March 1995, evidence that the cockatoos sample some of the fruits has occurred, namely, orange, apple and pear where small bites have been seen on chunks of fruit (pers. obs.). Since the cockatoos still receive the seed mix scattered in the exhibit, their pattern of food preferences may be similar to that shown in Phase 3. Consumption of fruits may be an attempt for the birds to derive more energy from the diet while still avoiding the pellets.

Deficiencies in nutrient levels with regard to nutrient specifications derived by (Ullrey et al., 1991) for breeding and growing psittacines, were found for vitamin A levels in the diet (but only without the supplement). Of the essential amino acids the following were deficient for breeding in both phases: lysine, methionine, threonine, and isoleucine. This indicates that even without the seed mix, sufficient amounts are not present in the pellets and psittacine mix combination. There may have also been a cystine deficiency in both phases but the database was incomplete for that amino acid. Arginine was found to be deficient for breeding based on the food intake during Phase 2. There were no deficiencies of essential amino acids on a recommended allowance for maintenance, except for the unknown possibility of cystine.

The calcium:phosphorous ratio was not in the range of 1: 1 or 2: 1 as is favourable for vertebrates, in Phase 3 without the supplement. The ratio in Phase 2 was adequate. In respect to nutrient specifications of other mineral levels for breeding and growing psittacines deficiencies in both phases were found for sodium, potassium, copper, and manganese. The recommended nutrient allowances for maintenance were not met for potassium levels (Phase 2) or for manganese (Phase 3). Manganese is an important mineral in poultry production and deficiencies of it has been linked to a failure to maintain weight, a decrease in egg production and egg shell

strength and the hatchability of eggs. Muscular incoordination and perosis can result (Tollefson, 1982). Copper is essential in cross linking lysine in elastin (Jones, 1977 as cited by Tollefson, 1982) and its deficiency in a diet already compromised in lysine may have additional negative effects for a breeding pair or growing chick or possibly even for maintenance requirements.

The pair of cockatoos at MTZ appear to be active and healthy but Kollias (1995) observes that while a bird consuming seeds high in fat or oil, or other dubious high calorie foods, may appear to look well, it may be experiencing subclinical nutritional deficiencies. The cockatoos seem to be overweight, evidenced by their weight fluctuations over the course of the year (100 g for the female), and by other weights obtained for the species. Kollias (1995) discusses "fatty liver syndrome" which occurs in psittacines and although the precise causes are unknown, the dietary history of the syndrome suggests multiple nutrient deficiencies or excessive energy, fat (e.g. peanuts, oil seeds, cheeses), or vitamins offered to inactive birds.

The female cockatoo has shown fault bars on her feathers for some time although there is no conclusive observation about when this began to occur (pers. obs.). The condition cannot be definitely linked to nutrition over other stressors but may be worth *considering. Deficiencies* of several vitamins produce the alteration of skin and feathers; and deficiencies of some amino acids have also been implicated in such disorders (Tollefson, 1982). The estimates of vitamin levels of the cockatoo diet are not complete and should be more thoroughly reviewed. However, with the supplements in the diet, vitamin A, vitamin E and vitamin 03 were shown to be present in adequate amounts for both maintenance and breeding requirements, although vitamin 03 levels are barely at breeding requirement levels in phase 2. Tollefson (1982) cites Buttner's finding (1968) where high arginine requirements are especially high during growth of young birds and during molting because feather protein is high in arginine. Arginine was deficient in Phase 2 as compared to requirements for breeding and growing psittacines.

Methionine was deficient at requirement levels estimated for breeding and growing psittacines in all phases (Brue, 1994). Choline can spare the requirement for methionine (Brue, 1994). The choline content in Phase 3 was 817.5 mg/kg (dry matter basis) including supplements, although like most of the other vitamins the values do not include the levels provided by the psittacine mix's vegetables, dog chow, or pellets. The recommended allowance for maintenance for choline is 1000 mg/kg (Brue, 1 994). Presumably with some choline added by the pellets; dog chow, peas and beans in psittacine mix (the latter known to be adequate sources of choline), the choline level would at least reach the minimum level in Phase 3.

Lysine and methionine are recognized to be of particular importance for breeding and growing psittacines (Tollefson, 1982) and were deficient in both phases. Ullrey et al. (1991) reported peanuts, pumpkin/squash and sunflower seeds to be high enough in protein to meet the needs for growth. Pumpkin/squash seeds yield more methionine and cystine and are lower in fat than sunflower seeds (Ullrey et al., 1991). Another source of adequate methionine are peas, and these could be increased in the psittacine mix as an alternative to seeds. Dried parsley and spinach are a good source of lysine (Brue, 1994) and either dried or fresh could be tested for palatability, at least providing some improvement to lysine levels in the diet (Brue, 1994). Raw or cooked broccoli or raw corn appears to be a fair source of lysine (Abramson, 1991).

Sodium, potassium (Phase 2 only) and manganese (Phase 3 only), are low enough to be below the recommended allowance for maintenance. A good source of potassium can be derived from dried vegetables, and raw (or cooked) broccoli, and fair amounts of sodium can also be derived in dried leafy vegetables or dried carrots (Brue, 1994; Abramson, 1991) An adequate source of manganese is hemp seed, which is another oil seed but is also a good source of arginine (Tollefson, 1982). Although Boosey (1956) fed his Major Mitchell's Cockatoos on solely a seed diet, he recommended a "mere sprinkling of hemp every other day" and that it be given daily when the pair had young in the nest to feed as it was a "valuable rearing food". The level of copper was too low for breeding and growing psittacines in both phases but raw broccoli would appear to be a moderate source for copper (Abramson, 1991).

By adding some of the above food items to eliminate nutrient deficiencies which exist at the maintenance requirement level (sodium, potassium, manganese and possibly cystine) and at the level required for breeding and growth (arginine, lysine, methionine, threonine, sodium, potassium, manganese and copper), the impact of the new foods would need to be considered, such as possible over supplementation of iron which is already high in the diet, and parsley or spinach could add to that. Raw or cooked broccoli may be better but if unpalatable, cooked beet greens may be a fair source of lysine (Abramson, 1991). Kollias (1995) reports that there has been recent findings of hemochromatosis in psittacines, the accumulation of excessive iron in hepatocytes which results in inflammation, bile duct proliferation, necrosis, fibrosis or cirrhosis. It is unclear as to whether the disease directly relates to excessive iron in the diet or whether stress or genetic factors play an equally important role (Kollias, 1995). Increasing the amounts of vitamin and mineral supplements should be done with caution or alternative supplements sought.

To summarize, if parrot seed is continued to be used, it should be offered in smaller amounts, only scattered in the exhibit and perhaps offered less than daily. The consumption of pellets should be monitored to determine the optimum amount of seed mix that can be allowed without impacting on pellet consumption. The manganese deficiency may be corrected, however adding a small amount of hemp seed would correct the deficiencies of both manganese and the low arginine levels, the latter being a consequence even if "normal" levels of the pellets are eaten.

Alternatively, although many estimates of nutrient intake were inconclusive, especially for vitamins, the Wings of Life feed should be investigated more thoroughly for its value as a pelleted feed, despite its apparent palatability for the cockatoos. In addition, the dog chow in the psittacine mix needs to be analyzed in more detail. If the use of Wings of Life is continued and parrot seed is discontinued the protein level in the diet should be adjusted for breeding. Supplementary food which could be used with discretion may be pumpkin/squash seeds, hemp seed particularly during the breeding season, green food such as spinach or parsley (preferably dried) or cooked/raw broccoli. These would supplement the lysine that is lacking, with broccoli adding less iron to a diet already high in the mineral. Although one of the highest sources of iron is the Wings of Life feed, the iron may be somewhat reduced without the parrot mix containing oat groats and safflower (which are relatively high in iron). Peas, beans and corn (preferably raw) could be increased proportionately in the psittacine mix, as could be the soaked dog chow, all of which would add more nutrient value where deficiencies now exist and which appear to be palatable to the cockatoos.

The present study did not determine the intake of each bird, rather an estimate, and assumptions were made about consumption of components in the food mixes. Time constraints allowed for only sorting refused food into component parts in an attempt to minimize the error. For a more accurate record, the food mixes should be sorted down to component parts and weights of the components offered should be established. Ideally, an individual's food consumption could be measured separately but that does not approximate the influence which pair dynamics exhibit on food intake and nutrient requirements. Some behavioural observation about what food items are preferred by each bird would be the ideal determination about nutrient intake, as well as a measure of digestibility of the food. In addition, information needs to be gathered on more of the nutrient values for the Wings of Life pellets, especially vitamin content.

There are some possible serious deficiencies in the cockatoo diet both with the presence of seed and without it. The seed mix has been offered only scattered throughout the substrate of the exhibit, but the birds' weights reflect that there is still too much fat in the diet. The diet will need reevaluating before the pair can be expected to breed and raise chicks without effects on their health or that of the chicks. Brue (1994) recommends that "a moderately high plane of nutrition that will optimize body stores, allow ready repletion of depleted stores and provide adequate nutrition for chick growth is probably the simplest and safest means of dietary management".Through careful observation a well balanced diet can be tailored to the individuals it serves and create a true ideal, ensuring as little nutritional complications as possible for future generations.

ACKNOWLEDGEMENTS

The authors thank the staff of the Australasia pavilion, namely Eric Cole, Maria Franke and Karyn Tunwell for their assistance in data collection, comments and support for the project. The support from Oliver Claffey was instrumental in the completion of the project. Additional thanks go to Maria Franke for technical assistance. In addition, Bill Robinson and Lindsay Cooper volunteered their time to help with data collection and their time was greatly appreciated. We are also thankful to the staff at the following zoos for information about their Major Mitchell's Cockatoos and their respective diets:

Birmhingham's Jimmy Morgan Zoo
Reid Park Zoo
Rio Grande Zoo
San Diego Zoo
San Antonis Zoo

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Wings of Life pellets. Wings of Life, Elora, Ontario, Canada

Table 1. Composition and mean proportions of food mixes offered to Major Mitchell's Cockatoos at Metro Toronto Zoo

FOOD MIX	PSITTACINE MIX							
COMPONENTS[a]	kidney beans	dog chow	boiled rice	cookd corn	cooked gr.beans	cookd peas	cooked carrot	MTZ carn. v.m.supp.	bone meal
PROPORTION (mean %)	23	24	20	28	1	2	2	2	2

FOOD MIX	MIXED FRESH FRUITS					
COMPONENTS	grapes	strawberry	apple	banana	orange	honeydew melon
PROPORTION (mean %)	16	16	8	18	3	5

FOOD MIX	MIXED DRY FRUITS			
COMPONENTS	dried fig	dried apple	raisins	currants
PROPORTION (mean %)	13	4	7	10

FOOD MIX	PARROT MIX							
COMPONENTS[b]	oat groats	whole corn	peanut	sun-flower	saf-flower	milo	buck-wheat	dog kibble
PROPORTION (mean %)	17	15	8	27	13	13	2	5

[a] kidney beans are soaked, dog chow is "K 9 Selection", MTZ carnivore vit-min supplement.
[b] dog kibble is Purina.

Table 2. Food intake (as fed basis)* of a pair of Major Mitchell's Cockatoos on the Metro Toronto Zoo diet, recorded over 21 days

	PHASE 1				PHASE 2				PHASE 3			
FOOD ITEM	$\bar{X}$ AMT OFFER (g)	$\bar{X}$ AMT EATEN (g)	SD	R	$\bar{X}$ AMT OFFER (g)	$\bar{X}$ AMT EATEN (g)	SD	R	$\bar{X}$ AMT OFFER (g)	$\bar{X}$ AMT EATEN (g)	SD	R
PSITTA. MIX	80.0	35.4	8.1	20.0 to 45.8	80.0	31.7	10.3	11.3 to 39.6	80.0	23.1	18.2	2.1 to 60.3
BEAN-SPROUTS	10.0	4.8	2.8	2.3 to 8.5	10.0	3.2	1.8	1.4 to 5.6	10.0	0	0	0
FRESH, DRIED FRUITS	60.0	4.8	0	0	60.0	0	0	0	60.0	0	0	0
PELLETS	80.0	33.0	8.5	21.4 to 45.7	80.0	30.3	9.2	19.1 to 42.0	80.0	4.5	3.4	0
PARROT MIX	---	---	---	---	---	---	---	---	50.0	24.5	3.3	19.0 to 27.8

* Mean amounts offered and eaten, standard deviation (SD), and range (R).

NB Mixed fresh and dried fruits offered 3 times weekly.

Table 3. Nutrient intake of Major Mitchell's Cockatoos (per bird) on a dry matter and as fed basis over a 21 day period

NUTRIENT	PHASE 1		PHASE 2		PHASE 3		% DIFF[b] PH 2-3
	DM	AF	DM	AF	DM	AF	
ME[a]kcal/feed	---	97.61	---	86.97 (121.25)	---	73.44 (68.29)	-15
weight %	100	100	100	100	100	100	---
WATER %	---	26.25	---	24.79	---	17.25	-30
DRY MATTER %	73.93	73.93	75.21	75.21	82.75	82.75	+10
CRUDE PROTEIN%	18.04	13.33	18.41	13.85	24.01	19.87	+43
CRUDE FIBER %	14.51	10.73	14.46	10.87	16.99	14.06	+29
ASH %	5.12	3.78	5.25*	3.95*	4.59	3.80	-3*
FAT %	5.08	3.75	5.00	3.76	5.78	4.79	+27
linoleic acid %	1.39*	1.02*	1.40*	1.06*	0.72*	0.60*	-43*

[a]Metabolizable Energy content / feed (g) obtained from protein, fat and carbohydrate portions of the diet. Bracketed values represent ME content / feed based on gross energy (as fed basis) values of the diet.

[b]Percent difference between phases 2 and 3 nutrient levels (as fed basis).

*Values were 50% of the data was not provided for food items regarding that nutrient.

Table 4. Estimated amino acid intake on a dry matter (DM) and an as fed (AF) basis for Major Mitchell's Cockatoos (per bird) over a 21 day period

NUTRIENT	PHASE 1 DM	PHASE 1 AF	PHASE 2 DM	PHASE 2 AF	PHASE 3 DM	PHASE 3 AF	%DIFF PH2-3*
ARG %	0.90	0.66	0.92•	0.69•	1.46	1.21	+75•
TRYP %	0.11 •	0.08•	0.10•	0.07•	0.27	0.22	+214*
LYSINE %	0.70	0.52	0.72•	0.54•	0.72	0.60	+11•
METH %	0.23	0.17	0.23•	0.17•	0.34	0.28	+64•
CYS %	0.0•	0.00•	0.00•	0.00•	0.24	0.20	+100•
PHENYL %	0.52	0.39	0.53•	0.40•	0.83	0.69	+73•
TYR %	0.57	0.42	0.58•	0.44•	0.59	0.49	+11•
HIST %	0.35	0.26	0.35•	0.27•	0.44	0.36	+33•
ISO %	0.47	0.35	0.48•	0.36•	0.73	0.60	+66•
LEUC %	1.22	0.90	1.24•	0.94•	1.41	1.17	+24•
THREO %	1.06	0.78	1.11•	0.83•	0.73	0.60	-27•
VAL %	0.60	0.44	0.60•	0.46•	0.93	0.77	+67•
TAUR %	0.00*	0.00•	0.00•	0.00•	0.00*	0.00*	0•

*percent difference in nutrient concentration of phases 2 and 3 (as fed basis).

•values where 50% of the database was not provided for food items regarding that nutrient.

Table 5. Estimated vitamin intake on a dry matter basis (DM) and as fed (AF) basis for Major Mitchell's Cockatoos (per bird) over a 21 day period

NUTRIENT	DM PHASE 1	AF	DM PHASE 2	AF	DM PHASE 3	AF	%DIFF*
VIT.A IU/g	2.65	1.96	2.88(9.33)	2.17(7.05)	2.92(10.59)	2.42(8.79)	+11
CARO.mg/kg	2.02	1.50	2.06(2.00)	1.55(1.51)	1.95(1.88)	1.62(1.57)	-4
$VITD_3$ IU/g	0.51	0.38	0.00(1.83)	0.42(1.36)	0.47(1.96)	0.39(1.62)	-7
VIT.E mg/kg	79.24	58.58	75.58(445.7)	56.84(337.1)	74.71(514.8)	61.82(427.5)	+87
THIAM MG/KG	1.64	1.21	1.69(2.69)	1.27(2.03)	3.32(4.45)	2.75(3.69)	+116
RIBO MG/KG	1.54	1.14	1.62(4.21)	1.22(3.18)	2.26(5.31)	1.87(4.41)	+53
NIACIN MG/KG	12.82	9.48	13.15(28.11)	10.04(21.26)	25.68(42.79)	21.25(35.54)	+111
PYRID. MG/KG	1.50	1.11	1.45(3.00)	1.09(2.27)	3.24(5.02)	2.68(4.17)	+145
FOLAC.mg/kg	0.30	0.22	0.31(0.51)	0.23(0.38)	0.51(0.75)	0.43(0.62)	+87
VIT.B_{12} mg/kg	0.02	0.02	0.02(0.07)	0.02(0.06)	0.02(0.08)	0.02(0.07)	0
PANTO mg/kg	2.40	1.78	2.41(5.54)	1.81(4.19)	9.48(12.96)	7.84(10.76)	+332
CHOL mg/kg	77.79*	57.51*	84.67(281.0*	63.69(212.5*	602.2(817.5*	498.3(678.9)	+682*
BIOTINmg/kg	0.01*	0.01*	0.01(0.04)*	0.01(0.03*	0.19(0.21*	0.15(0.18)	+1400*
VIT. C mg/kg	98.87*	73.09*	92.67(179.2*	69.70(135.5*	54.87(159.1*	45.41(132.1)	-34*

*Percent difference in nutrient concentration between phases 2 and 3 (as fed basis).
*Values where 50% of the database was not provided for food items regarding that nutrient.
Value in brackets represent levels after the addition of three vitamin-mineral supplements.

Table 6. Estimated mineral intake on a dry matter basis (DM) and as fed (AF) basis for Major Mitchell's Cockatoos (per bird) over a 21 day period

NUTRIENT	DM PHASE 1	AF	DM PHASE 2	AF	DM PHASE 3	AF	%DIFF*
CALCIUM%	0.44	0.32	0.43(0.65)	0.32(0.49)	0.53(0.79)	0.44(0.66)	+37
PHOSPH.%	0.29	0.22	0.28(0.30)	0.21(0.23)	0.65(0.66)	0.54(0.55)	+154
MAGNES.%	0.10	0.08	0.10(0.10)	0.07(0.07)	0.33(0.32)	0.27(0.27)	+285
POTASS.%	0.30	0.22	0.29(0.30)	0.22(0.23)	0.65(0.64)	0.54(0.54)	+145.0
SODIUM %	0.05	0.04	0.05(0.05)	0.04(0.04)	0.11(0.10)	0.09(0.09)	+125
IRON MG/KG	261.6	193.0	269.7(278.0)	202.9(210.9)	159.9(174.7)	132.3(145.1)	-34
ZINC MG/KG	132.4	97.8	136.6(142.0)	102.7(107.4)	55.38(64.59)	45.83(53.64)	-55
COPP.MG/KG	16.84	12.45	17.42(17.53)	13.10(13.26)	9.54(9.95)	7.90(8.26)	-39
MANGmg/kg	86.6	63.7	90.16(95.2)*	67.81(72.01*	36.51(44.41)	30.22(36.88)	-55
SELENmg/kg	0.41*	0.30*	0.42(0.45)*	0.31(0.34)*	0.21(0.26)	0.17(0.22)	-45
IODI.mg/kg	0.42*	0.31*	0.46(1.48)*	0.34(1.12)*	0.46(1.68)*	0.38(1.4)*	+11
COBALT mg/kg	0.63*	0.47*	0.69(2.24)*	0.52(1.7)*	0.77(2.62)*	0.64(2.17)*	+23*

*Percent difference in nutrient concentration between phases 2 and 3 (as fed basis).
*Values where 50% of the database was not provided for food items regarding that nutrient.
Values in brackets represent levels after the addition of three vitamin supplements.

Table 7. Percent consumption of food items (as fed basis) offered to Major Mitchell's Cockatoos when a seed mix is offered.

FOOD ITEM	$\bar{X}$ AMT EATEN PER PAIR PH2	PH3	$\bar{X}$ AMT EATEN PER BIRD PH2	PH3	PERCENT CONSUMPTION PH2	PH3
PSITTACINE MIX	31.8	23.1	15.9	11.5	39.7	28.8
kidney beans, soaked	7.3	(5.3)*	3.7	2.7	39.7	(28.8)
dog chow[a], soaked	6.6	(5.5)	3.3	2.8	34.3	(28.9)
boiled rice	5.4	(4.6)	2.7	2.3	34.0	(28.9)
cooked corn	8.9	(6.5)	4.5	3.2	39.7	(28.9)
cooked green beans	0.3	(0.2)	0.2	0.1	38.8	(28.8)
cooked peas	0.6	(0.5)	0.3	0.2	40.0	(28.8)
cooked carrots	0.6	(0.5)	0.3	0.2	47.9	(28.8)
BEANSPROUTS	4.8	0	2.4	0	37.9	0
WINGS OF LIFE PELLETS	30.3	4.5	15.2	2.3	37.9	2.0
PARROT MIX	---	24.1	---	12.1		48.3
oat groats	---	3.8	---	1.9	---	44.2
corn	---	2.3	---	1.1	---	4.5
peanuts	---	1.5	---	0.8	---	37.3
sunflower	---	6.6	---	3.3	---	49.0
safflower	---	3.2	---	1.6	---	48.6
milo	---	3.0	---	1.5	---	45.5
buckwheat	---	0.4	---	0.2	---	40.0
kibble[b]	---	1.1	---	0.6	---	45.2

* Values in brackets indicate estimated consumption based on proportions of components in the mix.

[a] K-9 Selection dog chow

[b] Purina brand dog kibble