Preliminary study into the effects of diet variation in Frugivorous native birds

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INTRODUCTION

Frugivorous birds, particularly those in the family Oriolidae, namely the Australiasian Figbird (*Sphecotheres vieilloti*) and the Olive Backed Oriole (*Oriolus sagittatus*) are commonly handed in to wildlife rescue centres within their range (8-17% of bird intake during peak season) and are a regularly encountered species in zoological institutions and private softbill collections. Despite their frequency of encounter, many carers and keepers face common issues with their maintenance in captivity, both short and long term. The principal issues faced includes loose and voluminous faeces, as well as syndromes involving regurgitation, abdominal swelling and sudden death. Some of these issues can be attributed to specific disease states such as bacterial infections, fungal (*Candida*) infections and parasitic disease, particularly flagellate protozoa and Leukocytozoon blood parasites. The vast majority of these birds however have no specific indications of disease and follow a pattern of initial willingness to feed and grow followed by slowed begging behaviour or reduced appetite and chronic weight loss. Numerous causes for this 'syndrome' have been postulated but management is often unsuccessful and results in many carers ceasing to work with these species. I have worked with figbirds and orioles closely for the last 12 years. I have maintained them both as rehabilitation cases and as breeding birds in my own aviaries and in zoological collections in which I have worked. Over this time I have also observed mortality syndromes and it is the intention of this study to elucidate what I believe to be the most common cause of this issue, ***osmotic diarrhoea***. This is primarily a husbandry related disease influenced by the selection of ingredients fed to these birds.

The choice of fruits utilised by carers and keepers is influenced by a number of factors such as:

- Availability – seasonal availability of certain ingredients will greatly influence the diets offered. It is uncommon for carers/keepers to have out of season fruits stockpiled for later use.
- Cost – The vast majority of wildlife carers are volunteers. The diets fed need to be purchased within the budget of the individual. Carers with numerous individuals to feed are more likely to select ingredients that can be purchased at a lower price or at a discount for bulk purchase. These items will predominate in the diets offered.
- Preparation – Ingredients that are easy and faster to prepare are more likely to be included in a diet than those that require preparation such as peeling or are difficult to chop into appropriate sizes.
- Storage – Ingredients that are long lasting under storage conditions are more likely to be used than those that spoil rapidly. This also applies to those that spoil quickly in the prepared diet once fed.
- History – Numerous diets have been offered to these species over the past few decades. Many of these diets are written into protocols and handed down from carer to carer with little change in their components. For the most part, these are then considered to be 'normal' diets for these species.

- Natural Perception – I have commonly encountered carers that refuse to feed certain foods as they are perceived to be 'unnatural' components of the diet. In reality, with the exception of native fruits, the vast majority of ingredients are unlikely to be accessible or consumed by a wild individual.
- Variety – Whilst variety is the spice of life, variety does not determine diet suitability. There is a misconception amongst frugivore enthusiasts that the more ingredients that are included, the more nutritional the diet is likely to be, as there will be a greater 'balance of nutrients'.
- Aesthetics – The appearance of the food in the bowl is, for many keepers, an important aspect of food selection. Particularly in a public situation, a food bowl with an attractively coloured mix of food is often deemed to be more appropriate than a bowl with 2-3 ingredients. There is for some keepers a requirement that the diet is anthropomorphised to resemble a 'fruit salad' that they would be happy to consume themselves.

A primary aim of this study is to suggest diet components that tick many of these boxes and allow carers/keepers to provide a standardised diet throughout the year that is easily obtained, easily stored, rapidly prepared, cost effective, aesthetically pleasing and most importantly, provides appropriate nutrition and digestion.

METHODS

The birds in this study were acquired as rehabilitation birds under Wildlife Rehabilitation Licence WIRP16358215. The study took place at my home residence. The data was collected during the normal feeding practices for these species, with only the diet changing, within the normal range of diets usually offered to these species in care. The birds utilised were self-feeding so that diets could be offered ad libitum. To encompass a range of current feeding practises, birds were sourced as direct wild hand-ins (orphans) which were subsequently raised to adulthood and from other carers/wildlife rehabilitation centres after they had raised them on their preferred diets. The birds were housed in a temperature controlled room at 26 C with a day night cycle of 12 hours light:12 hours dark supplied by cool daylight LED tubes. Light was provided from 5am to 5 pm. The birds were housed in wire floored cages (measuring 60 cm x 40 cm x 40 cm) with a catching tray underneath to collect faecal material. Flat bottomed stainless steel food bowls were supplied at ground level, immediately in front of the main enclosure perch. Each bowl held, when full, a maximum of 350 grams of food and 2 bowls were made available. At 5 am each morning, the catching tray was removed, all faecal material was scraped up and the faeces were weighed on jeweller's scales. The food bowls were removed and any residual food was weighed so that the previous days intake could be recorded. Fresh food was then supplied.

The diets trialled were as follows:

- Diet 1 – Fresh Fruit. This is the 'classical' diet fed to these birds in captivity. It generally consists of a mix of seasonally available fruits, chopped into cubes of approximately 8-10 mm. The types of fruits fed include rockmelon, honeydew melon, watermelon, mango, banana, kiwi fruit, grapes, paw paw, mandarin, apple and pear. Carers typically add approximately 5-10g of a commercial insectivore supplement and/or 5 grams of a vitamin/mineral supplement per 150 grams of food. The insectivore supplement is provided to compensate for the insect larvae that are often presumed to be found within consumed fruits in the wild. These diets vary from carer to carer and week to week as local and seasonal availability of fruits occurs.
- Diet 2 – PCC diet – This is the diet which I have personally used for the past 8 years. It consists of a commercial frozen 'Peas, Carrots and Corn' product to which 10 grams of a commercial insectivore supplement and 5 grams of a vitamin/mineral supplement is added per 150 grams of food. The product is defrosted slowly overnight in the refrigerator.
- Diet 3 – PCC + Fruit – This is a 50:50 mix of the above 2 diets.
- Diet 4 – PCC Native mix – This diet comprises 1/3 PPC mix, 1/3 fresh Blueberries and 1/3 Native fruits (collected locally). 10g of a commercial insectivore supplement and 5 grams of a vitamin/mineral supplement is added per 150 grams of food. Native fruits include species such as Figs, Cordylines, Blueberry ash, palm fruits, elderberry and lilly pilly.

The diets were fed to the orphan birds from the time of admission to the time of self-feeding. After this period, the diet may remain the same or be changed to demonstrate changes in intake, faecal output and faecal consistency. If the diet was changed, it occurred over a 5 day period, following which 5 days of the test diet were offered.

Gut transition time was also examined for 2 groups of 4 birds each from Group 1 and Group 4 (see below) cohorts. Four artificially coloured seeds of *Syzygium* sp (a common natural food plant) were assist fed to each of the 8 birds. The time taken for the seeds to become present in the faecal material was recorded following close observation and ceased when all seeds were accounted for.

Faecal appearance was recorded for each of the groups. Some samples were photographed to demonstrate the appearance.

RESULTS

The diet modifications that were carried out were as follows:

- Group 1 - Fruit started, fruit maintenance
- Group 2 - Fruit started. Mixed fruit/PCC maintenance
- Group 3 - Fruit started, PCC maintenance
- Group 4 - PCC started, PCC maintenance
- Group 5 - PCC/Native start, PCC/native maintenance

The results were as follows:

	Average weight per bird (grams)	Average daily consumption per bird (grams)	% of body weight consumed daily	Average daily excretion per bird (grams)	% of body weight excreted daily
GROUP 1 Fruit start, fruit maintenance (n=8)	81.5	116.7*	143%	48.75	59.8%
GROUP 2 Fruit start. Mixed fruit/PCC maintenance (n=6)	85.5	122.7*	136%	54.16	63.4%
GROUP 3 Fruit start, PCC maintenance (n=4)	101.3	85	83.9%	39.8	38.9%
GROUP 4 PCC start, PCC maintenance (n=11)	98	56.25	65.4%	28.7	29.3%
GROUP 5 PCC/Native start, PCC/native maintenance (n=3)	116	50.26	43%	18.2	15.7%

*denotes maximum holding capacity of feed trays was 700g. More may have been consumed if it had been made available but time constraints limited access during the feeding day.

Gut transit time results were as follows:

Group	Time of First appearance	Time of last appearance	Average Gut Transit time
1 (n=16)	21 minutes	48 minutes	33 minutes
4 (n=16)	44 minutes	88 minutes	68 minutes

Faecal appearance varied greatly with each group as follows:

Diet group	Faecal appearance	Image of faeces
Fruit start, fruit maintenance (n=8)	Faeces are unformed and comprised undigested fruit materials and undigested seeds	
Fruit start. Mixed fruit/PCC maintenance (n=6)	Faeces are poorly formed and comprised partly digested fruit materials, seeds and undigested peas, corn and carrots	
Fruit start, PCC maintenance (n=4)	Faeces are partly formed into tubular stools. Some undigested fruit material, peas, corn and carrots are present as well as digested materials	
PCC start, PCC maintenance (n=11)	Faeces are well formed with a faecal and urate component. Occasional undigested peas, corn or carrot are present as well as empty pea and corn membranes.	

DISCUSSION

Frugivorous (fruit eating) birds play a valuable role in seed dispersal within native plant communities, particularly the diminishing rainforest communities. Plants produce fruits to entice animals to disperse their seeds. It is in the plant's interest to make the fruit as tasty as possible. The sugar levels of these fruits vary dramatically between plant species and between native fruits and commercial fruit species. Fruits with high fructose content and high caloric concentration are generally considered to be tastier and thus commercially produced fruits often have enhancement of these features when compared to the native fruits consumed by these frugivores under wild conditions. It is a normal feature of these birds to have shortened gut passage time so that fruits can be stripped of their outer coating but the internal seeds pass through undamaged. Looking at the results above it is not unexpected that even with the slowest gut transit times, some undigested material will still be passed through. This is observed in wild adult birds as well. It is the degree of digestion that varies between the different diet groups ranging from voluminous diarrhoea to well-formed faecal pellets as one might expect in a non-frugivorous bird. In my experience, it is the birds with voluminous diarrhoea that fail to thrive.

Osmotic diarrhoea occurs when too much water is drawn into the bowels. This occurs if the concentration of solutes in the gut lumen is higher than the concentration of solutes in the intestinal tissue. Solvents flow from areas of low concentration to high concentration to equalise the situation. If the concentration is not equalised, excessively watery faeces are produced and gut transit time is shortened resulting in diarrhoea. In the case of the frugivores, it is a significant variation in the intraluminal sugar content that appears to cause the primary issue. In fruits consumed by these birds, variable quantities of fructose and glucose are present. Typically, the sweeter the fruit, the higher the fructose levels, however it is not the fructose levels alone that determine the impact that it has on bowel function. Whilst fructose levels determine the degree of osmotic pull, glucose levels present in the same fruit may counteract the effect and limit the development of the diarrhoea. In the case of mammalian fructose intolerance, selection of fruits and vegetables with a Fructose to glucose ratio of <1 will avoid the development of fructose induced osmotic diarrhoea.

Although it is beyond the scope of this study, we must also consider other high molecular weight sugars when designing diets for frugivores. Galactans are oligosaccharides containing chains of the sugar galactose. Many species lack the enzymes to hydrolyze them into digestible components, so they are completely malabsorbed. Consequently, galactans can contribute to osmotic diarrhoea. Other dietary sources of galactans include lentils, chickpeas, kidney beans, black-eyed peas, broccoli, and soy-based products.

Looking at the typical diet ingredients fed across the range of frugivore diets, we can clearly see that the diet components with the higher Fructose:Glucose ratios are those associated with diets causing voluminous diarrhoea. This supports the concept and allows carers/keepers to develop diets that suit their needs if they feel more comfortable with other ingredients.

Diet Ingredient	Fructose : Glucose ratio
Mango	3.1
Apple	2.8
Honeydew Melon	2.1
Pear	2.1
Water Melon	2.0
Guava	1.6
Blueberries	1.4
Tomato	1.3
Red Currants	1.2
Pineapple	1.2
Capsicum	1.2
Raspberry	1.2
Gooseberry	1.1
Strawberry	1.1
Orange	1.1
Star fruit	1.1
Kiwi fruit	1.1
Sweet corn	1.0
Grapes	1.0
Banana	1.0
Green Pea	1.0
Peach	1.0
Cherries	0.9
Fig	0.9
Carrot	0.9
Mandarin	0.8
Sweet potato	0.8
Plum	0.6
Lychee	0.6
Paw Paw	0.3

|*Preferred ‘fruit’ types to be included in the daily diet

As can be seen from the results, the proportion of food consumed in the fruit based diets (143% of body weight) is vastly different from that of the PCC and PCC/native diets (65.4% and 43% of body weight respectively). The faecal output, and therefore the degree of digestive activity, was also equally different. This high input and output coupled with the shortened gut transit time means that despite feeding voraciously, these birds are getting very little nutrition from the food consumed. In addition, lost fluids are not typically being replaced and the birds are often visually dehydrated.

The results for group 2 are not surprising when you consider that the PCC mixture is considerable denser than the fruit mix diet. This means that overall food weight and overall faecal weight will be heavier and the denser food will not have had any time to be digested and reduced in bulk. I have on many occasions discussed the change from a fruit diet to a PCC diet with carers. Typically, if any change is made, it is to add the two together. Unfortunately, as long as the fruit is still fed, osmotic diarrhoea will persist and the PCC are passed in large amounts and completely undigested. Carers typically interpret this as the PCC causing the issue rather than the rapid PPC passage being a symptom of the pre-existing issue.

In group 3, despite changing to the PCC diet, intake and output were greater than for the group 4 and 5 birds. It appears that it takes at least 2-3 weeks for the gastrointestinal tract to 'normalise' after being started on a type 1 diet. In the short test period, the normalisation was incomplete so higher intakes and outputs were noted, as if the fruit diet had influenced the functional surface of the gut.

In group 4 we observe what I would consider to be more normal faecal outputs. Unlike the previous groups, the faeces are well formed into tubular stools with minimal identification of the contents possible. It is not uncommon for the occasional food item to pass through undigested and this varies from bird to bird. Some individuals are highly selective in which items they prefer to eat. Within a single group of birds, some favour peas, some corn and some carrot as their first choice upon initial presentation however all birds were observed to eat alternatives when their favourite was absent. My observations indicated that individuals that showed a personal preference for carrot, were more likely to have undigested pieces in their faeces. I suspect that this is simply a reflection of the likelihood that some carrot pieces may require a longer transit time to digest. It would be interesting to test if the degree of undigested material changed if the items were subjected to 'pre-digestion' processes such as finely chopping into smaller pieces, rather than whole items, prior to feeding.

Group 5 represents an ideal situation with regards to intakes and outputs. As expected, feeding diets that contain components that would typically be consumed in the wild is more likely to produce 'wild type' digestive activity. It would seem simplest then to recommend this diet above all others at all times. The difficulty however is that gaining access to native fruits is regional, seasonal and time consuming and is often beyond the scope of the average carer/keeper.

Average gut transit time is decreased by over 200% when fed on a fruit based diet. In order to maintain a positive nutritional energy balance (i.e. no period in which nutrition is not available), food needs to be available ad lib for adults and as least as often as the average gut transit time for juveniles. On this basis, juvenile birds being fed on a Group 1 diet would require feeding at least twice an hour to achieve this. Birds on a group 4 diet would however only require hourly feeds to achieve this status.

The ideal diet is one that is nutritionally sound, produces 'wild type' intakes and outputs, is easy to prepare, cost effective to use and available all year round without the need to substitute ingredients. It is hoped that the quantitative data presented here will allow better diet selection resulting in improved nutrition, reduced mortality and improved rehabilitation of these species. It is also hoped that the data will encourage the modification of diets consumed by other frugivorous birds such as fruit pigeons, bowerbirds and cassowaries.

Further studies are planned to include the testing of ‘frugivore pellets’ as a diet component and similar tests in fruit doves (*Ptilinopus* species).

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