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Should zoo foods be chopped: macaws for consideration

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Abstract
Globally, many zoological collections provide their animals with diets that are chopped into small chunks, yet there is limited empirical research to measure the benefits of this practice. Preparing chopped diets takes considerable amounts of zookeeper time, and may affect both the nutritional quality and desiccation of the food. While keepers have suggested that chopped foods could reduce aggression, recent studies have suggested that the inverse is true for a range of zoo-housed mammals. Additionally, whole food items may have benefits in terms of increased food manipulation and processing. Many food presentation studies have been conducted on mammals, yet similar studies on other taxa are sparse. To test the impact of food presentation, we provided two pairs of blue and gold macaws *Ara ararauna* with either chopped or whole fruit as part of their normal feed rations. Macaw behaviour was measured using instantaneous focal sampling, with continuous recording of events; fruit consumption and keeper preparation time for diets was also recorded. Overall, keepers spent significantly more time preparing diets containing chopped fruit ($P<0.001$). Birds appeared to eat more when provided with whole food (21.66 g) rather than chopped (15.52 g), but this was not significant ($P=0.206$). Macaw activity budgets remained relatively consistent irrespective of food presentation, however, a few key behaviours increased in frequency, including podomanipulation ($P<0.001$) and allofeeding ($P<0.001$) when whole food was provided, whereas resting behaviour significantly decreased ($P<0.001$). Not only are keepers able to save time when providing their macaws with whole food, but the macaws also appear to spend more time engaging with their meal, and therefore less time inactive. Future studies could determine whether whole foods can improve the activity budgets of other frugivorous zoo-housed birds.

Introduction

Should zoo foods be chopped?

The chopping of fruit and vegetables for animal diets is commonly practiced in many zoos and aquariums globally (Plowman et al. 2006). It has been suggested that chopped food may reduce aggression between group-housed animals, allow a greater diversity of foods to be offered, and increase foraging opportunities (Mathy and Isbell 2001). However, these hypothesised benefits have rarely been quantified in published research (Plowman et al. 2006; Brereton 2020), and further studies are recommended to determine whether such benefits are realised for animals.

In the wild, animals would not receive their food prepared into bitesize chunks, and there is growing evidence to suggest that many zoo animals may actually benefit from the provision of whole fruits and vegetables in their diets (Shora et al. 2018). The potential benefits of whole food items could include reduced aggression, a reduced risk of bacterial contamination and desiccation of food, and also time saved for keepers (Plowman et al. 2006).

Studies have been undertaken investigating the behavioural effects of whole food presentation for species including macaques *Macaca* spp. (Smith et al. 1989; Mathy and Isbell 2001; Plowman et al. 2006; Sandri et al. 2017), tapirs *Tapirus terrestris* (Plowman et al. 2006), and coatis *Nasua nasua* (Shora et al. 2018). For most studies, larger food items were shown to reduce aggression within the animal groups, in contrast to previous keeper belief. This may be because animals can select and transport a single, large item, and then process the meal in a safe position, rather than competing over a single, valuable resource (the food bowl). Mathy and Isbell (2001) however, identified different results for macaques, finding greater aggression when whole foods were given. The discrepancy between findings may be attributed to different methodologies (see Brereton 2020 for a review). For several studies, time spent engaged in food manipulation was also increased (Plowman et al. 2006; Shora et al. 2018). In rodents, large food items were often associated with food transport and hoarding behaviours, whereas small food items were not (Brereton 2021). Overall, animals from many taxonomic groups may spend more time engaged in active behaviours when whole food is provided.

Relatively few studies have investigated avian chopped and whole foods; however, as a well-represented taxa in zoos, there is huge scope for studies (Fidgett and Gardner 2014). Previous research on the behavioural effects of over-sized pellets identified that orange-winged amazons *Amazona amazonica* spent significantly longer engaged in podomanipulation when large pellets were available (Rozek et al. 2010). The parrots were highly motivated to gain access to this resource, lifting up to 480-g obstacles, even when normal-sized pellets of the same nutritional content were available (Rozek and Millam 2011). When over-sized pellets were removed, chewing behaviours on wooden enrichment blocks was significantly increased (Rozek et al. 2010), suggesting that the large pellets fulfilled a behavioural function for gnawing.

For psittacines, previous research has investigated the effect of pellet size (Rozek et al. 2010), and also enrichment on behaviour (Field and Thomas 2000 Azevedo et al. 2016). Some previous, effective enrichment ideas have included whole food as part of their protocol (Azevedo et al. 2016; Sandri et al. 2017).

Effects of food preparation

Upon processing, several metabolic and biochemical changes occur in fresh fruit and vegetables that affect their quality. Brecht (1995) suggests that upon chopping, the respiratory rate of fruits and vegetables may be increased, potentially by as much as 150%. This may result in a net decrease in the metabolisable energy available in foods, particularly if chopping occurs some time before the food is consumed (Hodges and Toivonen 2008). Chopping also increases the production of ethylene, which may result in fruit tissues becoming softer, and colour change such as yellowing or browning on cut edges may occur (Brecht 1995). These changes often affect the flavour of the food; for many fruits, these metabolic processes result in a more acidic flavour, and less palatable food (Hodges and Toivonen 2008). Softer, yellowing fruit items may become less attractive and palatable to animals, particularly if they have been in the exhibit for several hours.

The severity of chopping synergistically affects both ethylene production and fruit metabolism, with finer particle size resulting in increases in both attributes. In studies on cantaloupe melons, Portela and Cantwell (2001) demonstrated that the use of blunt knives may further accelerate these effects by damaging cell membranes and releasing hydrolytic enzymes (Hodges and Toivonen 2008). This may result in fruit reducing in quality more rapidly when cut using blunt equipment.

Desiccation also occurs in chopped produce as cut surfaces are exposed to air (Brecht 1995). The rate of desiccation depends on the size of food particles, the proportion of the cut surface area, the environmental temperature, humidity, and time since chopping occurred (Hodges and Toivonen 2008). While desiccation may be negligible in recently chopped foods, significant water loss may occur in foods left in exhibits in warm weather (Watada et al. 1996). For some frugivorous birds that rarely use water sources for hydration, this desiccation may be an issue (Fidgett and Gardner 2014).

Bacterial contamination of chopped foods has been studied extensively in the food production industry (Garg et al. 1990). The process of chopping foods creates meals with a greater moist surface area that may support bacterial growth (Brecht 1995). Whole foods, by contract, are less susceptible to desiccation as plant fluids are normally protected by fruit skins and peels. Knives and equipment used to prepare foods could, in some circumstances, be sources of bacterial contamination.

The chopping of diets may be costly in terms of keeper time for large zoos. For example, Birdworld in Farnham, England state that roughly 10.5 hours of keeper time per week is spent on chopping fruit alone (Figure 1). If animal behaviour and welfare is not affected by food presentation, it seems reasonable to suggest that this time could be devoted to other practices, giving keepers more time for enrichment preparation or cleaning.

To summarise, there are several potential problems associated with chopped food that could result in reduced food quality. These effects may be minimal for some zoos, where food has recently been prepared and environmental temperatures are low. However, effects on food quality could be high, especially on occasions when fruits are chopped the day before feeding, or temperatures are hot.

Figure 1. Visitor information sign at Birdworld, Farnham (2019) displaying an estimated amount of time keepers spend chopping fruit per week.

Macaw diets

The blue-and-gold macaw *Ara ararauna* (Linnaeus, 1758) is one of the largest extant psittacids, and is well represented, with over 424 collections housing at least 2,000 macaws globally, according to the Zoological Information Management System (ZIMS 2019). Described as a frugivore, Silva (2018) suggests that *A. ararauna* feeds on over 100 plant species across their wild range. This species also shows considerable dietary plasticity; for example, Santos and Ragusa-Netto's (2014) feeding ecology study in urban Brazil revealed that *A. ararauna* regularly feed on at least 21 different fruit and seed plants, several of which have been introduced. The items regularly eaten included the mango *Mangifera indica*, coconut *Cocos nucifera* and Malabar almond *Terminalia catappa* (Santos and Ragusa-Netto 2014). Studies by Tubelis (2009) identified macaws feeding on a further seven species of fruits and palm nuts.

Macaws of the genus *Ara* possess several adaptations for tackling hard-bodied fruits and nuts, including large, nutcracker-shaped beaks, mobile tongues and zygodactyl feet for manipulating objects (Levey and Rio 2001). Macaws also have considerable memory, which may aid in locating fruiting trees (Ragusa-Netto 2006). These birds also show great capability in completing cognitive challenges in the wild and in captivity (Uribe 1982; de Almeida et al. 2018). Given their ability to solve problems, and their anatomical adaptations for dissecting fruit, the provision of whole fruits and seeds could be valuable for captive macaws (Veloso et al. 2014).

A. ararauna has been the subject of several enrichment studies (Uribe 1982; de Almeida et al. 2018). Previous studies used behaviour and glucocorticoid metabolites to assess the welfare of animals (Williams et al. 2017; de Almeida et al. 2018). Ethograms have been validated for many macaws of genus *Ara*, and previous studies have associated positive welfare with calm vocalisations (Williams et al. 2017), reduced pacing and increased locomotion (de Almeida et al. 2018), and increased prevalence of allofeeding behaviour (Veloso et al. 2014).

A variety of enrichment devices have been developed, including fruit kebabs (Field and Thomas 2000), corn cobs and sunflower rolls (de Almeida et al, 2018) and over-sized pellets (Rozek and Millam 2011). The provision of whole coconuts and pumpkins was also practiced by Azevedo et al. (2016). Macaws have been shown to engage in contra-freeloading behaviour, frequently working for food even when the same items are freely available (Rozek and Millam 2011).

Table 1. Age, location and sex of study subjects.

Individual	Year hatched	Sex	Collection
1	2010	Male	Beale Wildlife Park
2	2009	Female	Beale Wildlife Park
3	2003	Male	Shepreth Wildlife Park
4	2002	Female	Shepreth Wildlife Park

While mammals have been the primary study focus for previous chopped food studies, frugivorous Aves may also benefit from an evidence-based approach to diet presentation. Given the plethora of behavioural research on the species, *A. ararauna* is a good animal model to determine the welfare impact of providing chopped or whole food items.

Methods

Subjects

Two pairs of blue and gold macaws from two British zoological collections were selected as subjects for this research (Table 1). Observations were conducted at Beale Wildlife Park and Gardens, Lower Basildon, Reading, between November 2017 and January 2018 and Shepreth Wildlife Park, Shepreth, Cambridge, from September 2018 to December 2018. A total of 84 hours of behavioural observations were collected for each pair, amounting to 168 hours. Prior to the study commencing, ethical approval was granted by the Ethical Review committee at University Centre Sparsholt, and by both collections involved.

Beale Wildlife Park and Gardens

The two birds were exhibited in an outdoor aviary, with access to indoor quarters. Throughout the study, both macaws were provided with ad-libitum assess to 'Country Wide Super Deluxe with Fruit' parrot seed mix. In addition to the seed, 50 g of fruit was provided, either chopped into cubes, or as whole food items for the pair of birds. Food items were provided at 0845 each day as per the normal husbandry routine. The same keeper was responsible each day for preparing the diet. The pair shared their enclosure with two Jenday conures *Aratinga jandaya*. Whilst the conures had access to the same food resources as the macaws, no attempt was made to record the behaviour of this species. There was minimal interaction between the Jenday conures and the blue and gold macaws.

Shepreth Wildlife Park

Shepreth Wildlife Park's macaws were housed in a single-species outdoor aviary, with additional indoor housing to which the animals had constant access. Both macaws were provided with ad-libitum access to a standard seed diet, Prestige Parrots seed, produced by Versele-Laga. In the study, 50 g of fruit items were provided at 0845 each day, either as whole food items or were chopped into cubes. The same keeper prepared the diet each morning. No other changes to the normal husbandry routine were undertaken.

Food presentation

Subjects in all collections had access to parrot seed mixes as per normal husbandry practice, placed at their normal locations within the enclosures at the time of the study. The fruit component changed on a daily basis, but the diet consisted of apple, peach and pear for both pairs of birds. During half the observations, the birds were provided with chopped food, cut into approximately 2 cm^3 pieces as per regular husbandry practice at the collections. On other observations, whole fruit items were provided. The food presentation schedule was randomised, so that the macaws did not become accustomed to one form of presentation. Preparation time, including time spent washing equipment required to prepare feeds, was measured in minutes and seconds for both chopped and whole conditions. In all cases, the fruits were placed in locations within the enclosure that were easily accessible to all subjects. The weight of the fruits before feeding was compared to the weight of the fruit remains to provide a measure of how much food had been consumed over the period of the observation

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Table 2. Ethogram for macaw including state and event behaviours, adapted from Uribe (1982).

Behaviour	Explanation
State	
Allopreen	One macaw is seen preening the feathers of the other macaw using beak.
Autopreen	One macaw is seen preening own feathers using beak.
Climb	Movement of the feet and/or beak resulting in a vertical change of location.
Feed	Macaw is seen swallowing a type of food.
Fly	Movement of wings resulting in elevation off the ground and moving location.
Forage	Use of feet or beak to interact with objects to search for food items.
Walk	Movement of the feet to result in a horizontal change of location.
Out of Sight	Inability to see where the bird is situated; behaviour is unknown.
Rest	A lack of movement, can be resting on perch, bars, or other features of the enclosure.
Event	
Allofeed	Food from the beak of one macaw is seen passing to the beak of the other macaw who then swallows the food.
Allopick	Macaw is seen plucking the feathers of another macaw followed by visual falling of the feather and potential vocalisation of the victim.
Auto-pick	Macaw is seen plucking own feathers followed by visual falling of the feather.
Beak manipulation	Flesh from the food is removed from the skin using the beak.
Inter-aggression	Macaw pursues or attempts to bite another species housed in the exhibit.
Intra-aggression	Macaw pursues or attempts to bite another macaw housed in the exhibit.
Podomanipulation	Holding of and interaction with food items using a foot. The macaw may also use its beak to feed on the food during this time.
Chew	Opening and closing of beak on non-edible items in enclosure including bars and branches.
Vocalisation	Loud squawking noise from macaw.

day of six hours to determine the effect of food presentation on consumption. On removal of food, any dropped items were also collected up from the floor of the exhibit, which was smooth concrete and therefore facilitated collection. A correction factor for desiccation was not applied to the fruit weights, but this should be considered in future studies.

Behaviour and environmental variables

Temperature and humidity were recorded for all observations, with standardised information collected from the Met Office (2018). Additionally, the date, time and weather condition for each observation was recorded.

A standardised ethogram was developed and used at both zoological collections (Table 2). Instantaneous focal sampling at 60-sec intervals for 1-hour observation periods was used to collect behavioural data (Martin and Bateson 2007). Event behaviours were collected using continuous focal sampling as per Martin and Bateson (2007).

Statistical analysis

The effect of chopped or whole food presentation on behaviour was analysed using a generalised linear mixed model (GLMM) with binomial distribution and a log link function and also assessed how these varied with temperature, time of day, sex and collection. The different individuals in the study were set as a random factor to control for the repeated measures aspect of the design. Each behaviour was analysed separately taking the total frequency of each event behaviour (averaged per day) as the response variable. Statistical analysis took place using Minitab 17 (Minitab 17 Statistical Software, 2010). Behavioural data were tested for normality and determined to be not normally distributed. Where multiple tests were conducted on one behaviour, a Bonferroni correction factor was applied.

The data on the amount of time taken to prepare diets and amount of food eaten were also tested for normality. Both datasets were determined to be non-parametric, so Mann Whitney-U tests were used to identify significant differences between the chopped and whole food presentations.

Results

Behaviour

Activity budgets were developed to demonstrate the effect of food presentation on macaw state and event behaviour (Figures 2 and 3). The amount of time feeding significantly increased when fed a whole food diet compared with a chopped food diet (F=4.03, df=1, P=0.05) (Figure 4): there was also a significant difference between individuals (P<0.05). The number of times food was manipulated using the beak also increased for whole food presentation (F=26.23, df=1, P<0.001); individual was not significant (Figure 5). Similarly, there was a significant increase in the amount of time spent allofeeding (F=7.23, df=1, P=0.01); males engaged in this behaviour more often (P=0.01). There was a significant decrease in time resting (F=5.85, df=1, P =0.019) and number of vocalisations (F=4.06, df=1, P=0.05) with no significant differences between individuals (Figure 6). Time of day, collection and temperature were not significant predictors for any of the models. There was no significant difference with other behaviours, in particular with regards to the frequency of aggression.

Amount of fruit eaten

The amount of fruit eaten was measured for each observation period by deducting the amount of fruit remaining from the amount of fruit offered. On average, the macaws appeared to eat more when whole foods were offered (21.66 g) than chopped (15.52 g) (Figure 7); however, this was not statistically significantly different, (U=5.4, n1=n2=15, P=0.206).

Food preparation time

Time spent preparing food and washing equipment was averaged for both food presentations (Figure 8). Keepers spent significantly longer preparing food and washing equipment for the chopped condition (average 242.70 sec) than the whole condition (average 22.35 sec) (U=171.66, n1=n2=15, P<0.001).

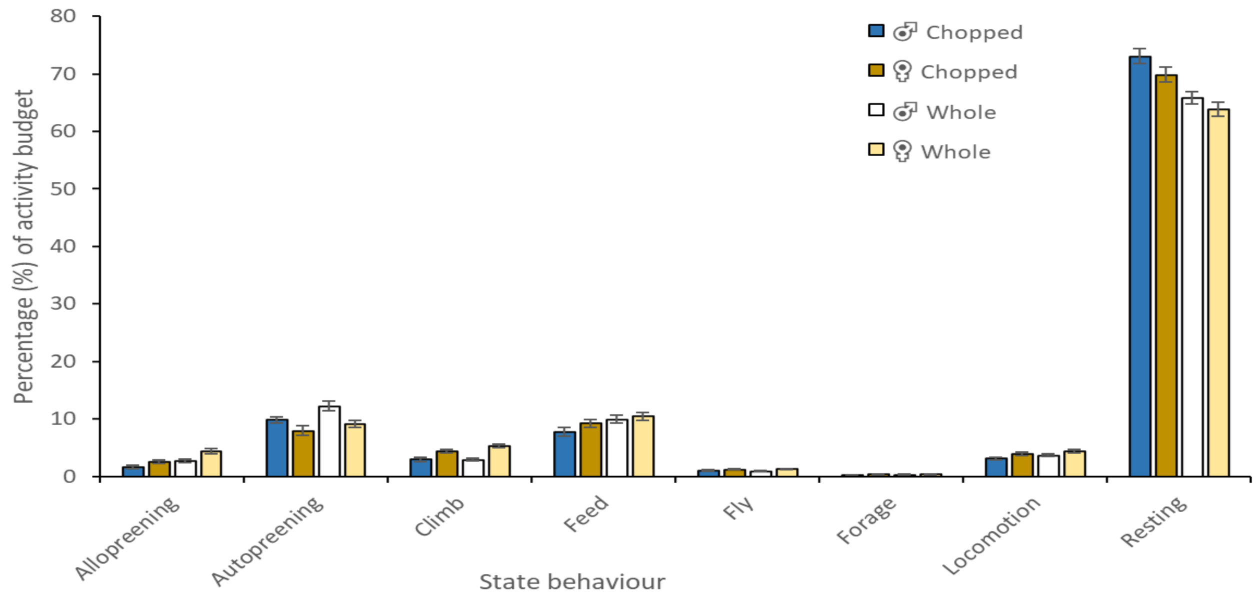

Figure 2. Activity budget of macaws when provided with either chopped or whole food. Data have been pooled for both males and both females respectively.

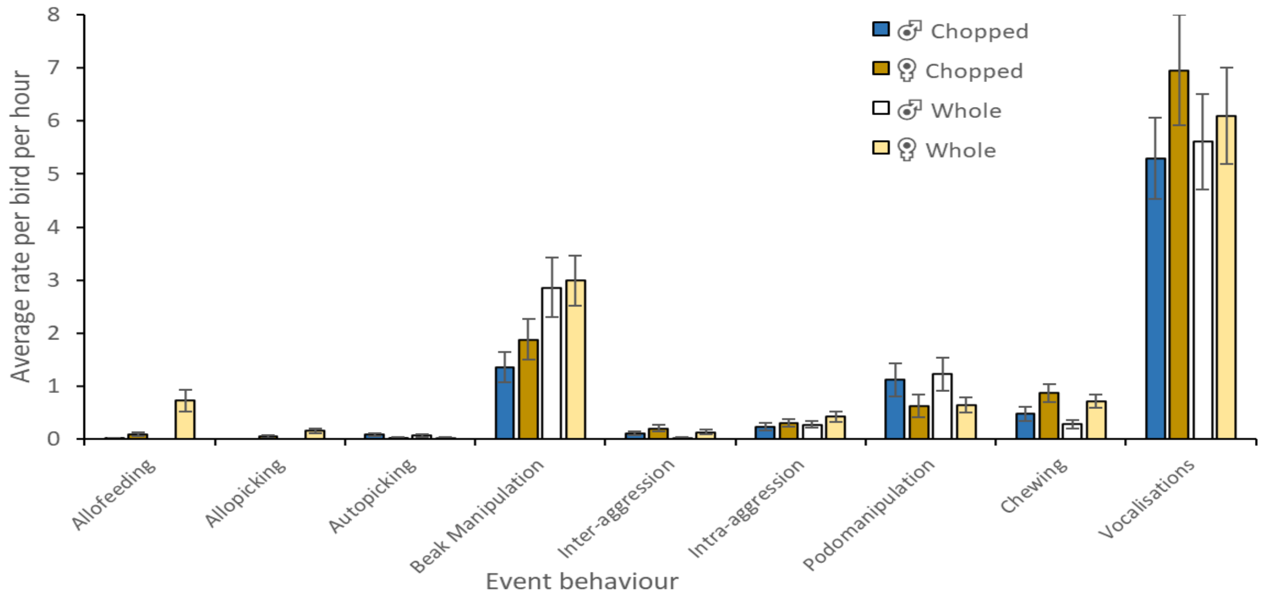

Figure 3. Macaw event behaviours when provided with either chopped or whole food. Data has been pooled for both males and both females respectively.

Discussion

Effect on behaviour

Overall, food presentation impacted some behaviours for the two pairs of macaws. Several state behaviours appeared to become more prevalent under whole conditions: in particular, allopreening, autopreening and feeding occupied significantly more of the macaw activity budget when whole food was given. Additionally, resting behaviour decreased when whole foods were provided, as did vocalisations. Effect sizes for most of the behaviour changes, however, were relatively small.

This consistency in macaw activity budget is promising, as it suggests the birds have not been negatively affected by the change in food presentation. Macaws have been shown to be neophobic when introduced to new foods (Brightsmith 2012), yet the birds did not show aversive behaviours when provided with whole items. Conversely, the birds appeared to eat more fruit when whole foods were offered, though this was non-significant.

Previous studies on zoo animals often suggest that an increase in activity level is beneficial for welfare (Rozek and Millam 2011; Sandri et al. 2017). There is evidence to suggest that many species spend a considerable proportion of their day hunting or foraging for food and mates, and that high levels of inactivity are unnatural (Shora et al. 2018). In the wild, *A. ararauna* are described as nomadic, and spend long periods of their time searching for sporadic fruiting trees and feeding (Tubulis 2009). A decrease in inactivity could therefore be considered beneficial for welfare. This suggests that the birds are spending more time engaging in activity, which is more reflective of their wild habits.

In contrast, the amount of time spent in autopreening increased when whole foods were provided. Preening is considered to be an essential maintenance behaviour for birds (Millam 2000) and is a key part of the activity budget of most birds. It is hypothesised that the increase in preening behaviour may be linked to fruit manipulation and beak hygiene. In feeding on large fruit items, birds may dirty their feathers with fruit juice and pieces, which need removing. The provision of large items may therefore encourage birds to spend greater amounts of time preening (Tubulis 2009).

While a significant increase in podomanipulation was not evident, there was a significant increase in beak manipulation for the macaws in the study. The macaw beak has been shown in previous enrichment studies to be capable of opening a range of enrichment items (Azevedo et al. 2016; de Almeida et al. 2018). Providing whole foods allowed macaws to use their beaks to greater effect. Many studies have shown that macaws actively engage in contra-freeloading behaviour in captivity (Rozek et al. 2010; Veloso et al. 2014); whole foods may therefore provide a challenge for macaws.

One of the greatest concerns for keepers when providing whole foods is that aggression bouts will increase for group-housed animals. No change was identified in the prevalence of aggression for both food presentations, which is relatively positive. Uribe (1982) has identified a range of aggressive behaviours associated with macaws in groups, including biting, chasing and feather plucking. Fortunately, these did not occur more frequently when whole foods were given, supporting previous findings by Shora et al. (2018) and Plowman et al. (2006). From observations, birds appeared to take one single, large fruit item and spend time engaged in feeding on it, similarly to the findings of Rozek et al. (2010). Perhaps this meant that the birds were too busy feeding to compete over food resources. By contrast, chopped food in a traditional bowl represents a single resource which the macaws could not take away to a perch. This mean that the birds were actively feeding in the same area. In mammals, Mathy and Isbell (2001) recorded that aggression increased when large food items were given. However, during each observation only two food items were provided for a small group of macaques. This is likely to have increased competition over resources as insufficient food was available for all animals. It is suggested that the frequency of aggression may decrease with whole food provision, but only when there are sufficient resources for all animals.

The significant increase in the frequency of allofeeding behaviour was an unexpected finding from this study. Allofeeding behaviour is normally associated with breeding and courtship in psittacines (Schmid et al. 2006). Millam (2000) suggests that for pair-bonded parrots, allofeeding may occur at any time of year as part of bond maintenance. This study investigated pairs of birds; therefore, it seems likely that allofeeding is linked to social behaviour and pair formation (Luescher 2016). Allofeeding occurred in both chopped and whole conditions, yet it is not known why this behaviour occurred significantly more frequently for whole foods. It is suggested that the natural behaviours of manipulating and chewing whole fruits may act as a trigger to

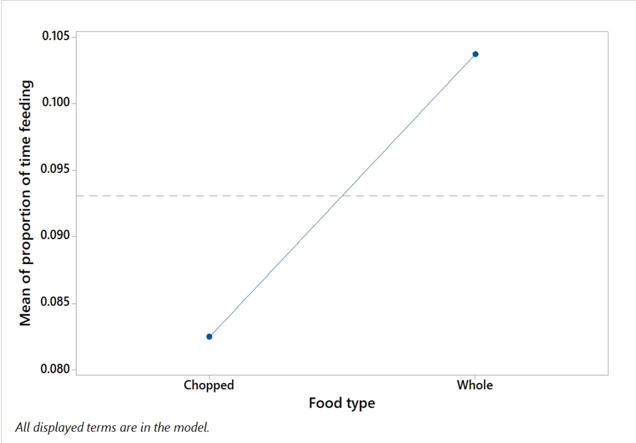

Figure 4. Main effects plot for the proportion of time feeding between different food presentations.

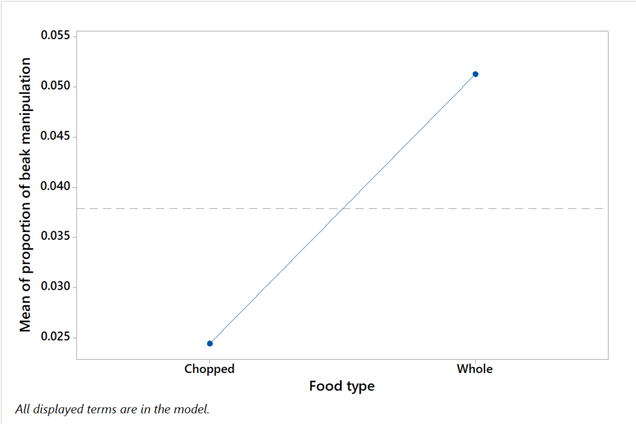

Figure 5. Main effect plot for the proportion of beak manipulation events between food presentations.

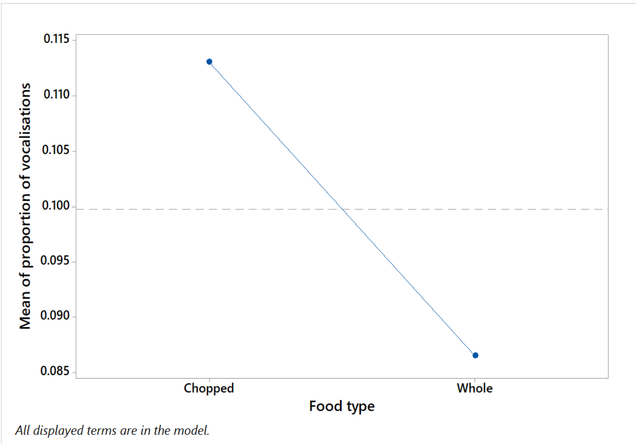

Figure 6. Main effects plot for the proportion of vocalizations between food presentations.

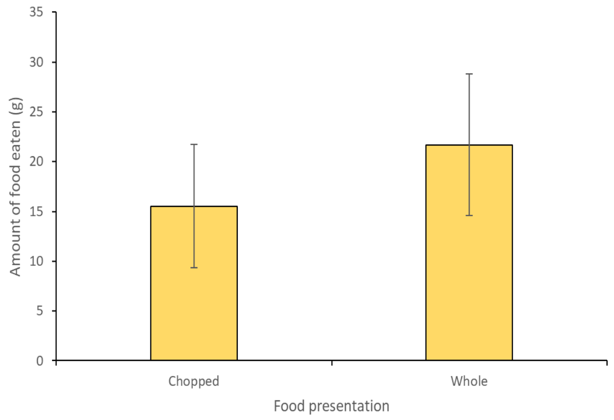

Figure 7. Pooled data on amount of food per observation for chopped and whole food presentations.

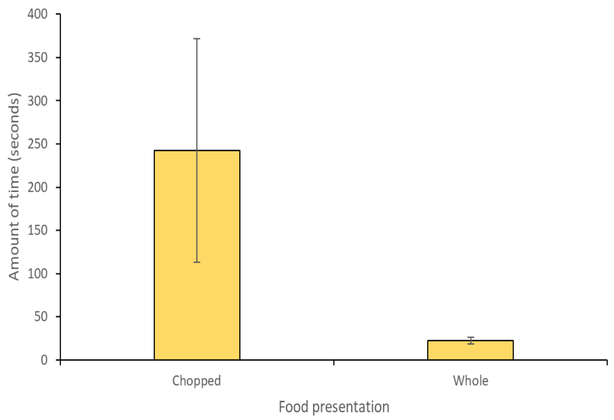

Figure 8. Amount of time keepers spent preparing and washing equipment for both whole and chopped food presentations.

encourage birds to allofeed. Whole foods could therefore have a value in the pairing, and possibly breeding of birds.

It is not known whether this whole food-triggered allofeeding phenomenon occurs in all macaws, or indeed in any other psittacines. However, anecdotal observations by the authors of yellow backed chattering lories *Lorius garrulus* showed similar results. This suggests that the allofeeding response could be prevalent across a wide range of parrots and may even extend to other taxa.

Keeper input

On average, the provision of whole food items for each pair of birds saved 91% of keeper preparation time. Many zoos keep a wide range of frugivores (Fidgett and Gardner 2014); considerable time could therefore be saved if animals are fed whole foods, even on a twice-per-week basis (Plowman et al. 2006). This time could be reallocated to other tasks, such as development of enrichment (Azevedo et al. 2016). Additionally, whole food is less susceptible to bacterial contamination (Watada et al. 1996) and desiccation (Hodges and Toivonen 2008). If whole foods do not significantly affect the activity budgets of macaws, it seems reasonable to suggest that this food presentation could be trialled.

As part of the development of this project, keepers and researchers from a range of British zoos have been consulted on their opinions on whole foods. Several key points have been raised for consideration. These, along with responses, are considered below:

• 'Whole food will reduce the diversity of fruits I can feed my birds each day. The birds would normally receive a fruit medley with at least nine different fruit types.' This is a valid point as, realistically, many types of fruits cannot be offered per day for whole feeds unless considerable waste is created. To overcome this, it is suggested to provide two or three different fruit types per day, and alternating the fruits offered. On a weekly basis, this may allow keepers to still provide variety in the diet. An extra benefit is that fruit consumption can be measured more accurately. For a chopped diet, measuring consumption of individual fruit types is difficult, as all fruits are normally mixed together. This could allow macaws to selectively feed on just a couple of fruit types without keepers necessarily noticing (Fidgett and Gardner 2014).

• 'There will be greater food waste as my macaw will only eat one bite and will drop the rest.' This may also be true in some circumstances. There are several ways to overcome this challenge; first, food could be presented in a bowl where it is difficult for the macaw to lift it away. Several collections have also experimented with impaling fruit items on enclosure furnishings such as branches (James Ellis, personal communication). This may encourage birds to use their enclosures more widely, and their feet and wings when feeding. This may be a more naturalistic feeding strategy; wild *A. ararauna*, for example, regularly feed on palm nuts which they must harvest in trees (Santos and Ragusa-Netto 2014).

• 'My birds won't be able to break through the skin of the fruit.' If birds have not been exposed to whole fruits previously, they may be unfamiliar with the food manipulation strategies required. To initiate whole food provision, it is suggested to provide food chopped into halves or quarters, so that birds can recognise the cut surfaces of the fruits. The current study utilised a range of soft-skinned fruits. However, wild macaws are known to tackle particularly tough-skinned items such as coconuts and palm nuts (Azevedo et al. 2016), so it seems likely that they can tackle much thicker-skinned fruits.

Future directions

The current study is an initial investigation into the suitability of whole fruits for captive macaws, and as such the results cannot be extrapolated to all macaws, or indeed all psittacines. However, the results are promising in that no negative behavioural changes were identified as a result of the food presentation change, and several positive indicators were identified. For future research, care should be taken when considering study species. Macaws of the genus *Ara* have many adaptations that allow them to process large, thick-skinned fruits and nuts, so it seemed likely that the macaws could process whole foods. Many other parrot species possess similar traits for processing fruits, though other taxa, such as fruit pigeons, may be less able to tackle these foods. Future projects considering the application of whole foods to other commonly housed zoo aves would be valuable. Additionally, future studies should consider the food selection of birds under both chopped and whole conditions, the skin thickness of candidate fruits, and also nutritional quality of feeds.

Zoo studies could also simulate exhibit conditions to determine the rate of desiccation, nutrient change and bacterial contamination of diets under different exhibit conditions. It has been suggested that finer particle sizes result in a more rapid degradation of foods (Brecht 1995). However, zoos present many unique environments, such as tropical houses, and hot dry reptile exhibits (Brereton 2020). Studies investigating the actual nutritional impact of these environments would therefore have merit.

Conclusions

1) The provision of whole foods resulted in significantly more time spent feeding, manipulating food and allofeeding, and significantly less time resting and vocalising for the two pairs of blue and gold macaws.
2) Several event behaviours, including beak manipulation and allopreening, occurred significantly more often when whole fruits were given. Whole fruits may therefore play a role in pair-bonding activities, and also as a form of enrichment.
3) Significant amounts of keeper time were saved when food was left whole. If keeper time can be saved with no detriment to their animals, whole food presentation could aid keepers in making more time available for other duties.
4) It is suggested that whole fruits have value for the husbandry of macaws, and tentatively suggested that similar results may be identified for similar species. Further studies for a range of frugivorous birds would be valuable to test this.

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