Zoo Food Preparation and Presentation

Subjects: Zoology

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From its foundations in agricultural science, zoo animal nutrition has developed into a biologically informed, evidence-based discipline. However, some facets of nutrition still make use of a more traditional approach, such as the field of zoo presentation. For example, it is common practice to prepare animal diets by chopping them into bite-size chunks, yet there is limited peer-reviewed evidence that explains the benefits and welfare implications of this practice. The chopping and placement of foods can alter desiccation rates, nutrient breakdown, and food contamination, so it is important to evaluate the implications of current practices. Here, the published literature on the behavioral impacts of different food presentation formats (such as clumped and scattered, and chopped and whole) is reviewed, with reference to a range of taxa. The current state of knowledge of the nutritional and microbiological effects of food presentation practices are also reviewed. Relevant research is available on the behavioral effects of some forms of zoo food presentation; however, relatively little research has been conducted on their nutrient composition effects or desiccation rates. Similarly, there are gaps in terms of the species that have been investigated, with a few mammalian taxa dominating the food presentation literature. Future research projects covering social, behavioral, and welfare impacts, and the nutritional and microbiological consequences of food presentation would further evidence-based zoo and aquarium management practices. Similarly, qualitative research surrounding keeper perception of food presentation formats would help to identify challenges and opportunities in this field.

food presentation | nutrition | zoo nutrition | food preparation | chopped food

1. Introduction

In the wild, many species spend considerable amounts of time hunting or foraging for food each day[1]. Once located, food needs to be properly processed: this may involve chewing of fibrous plant matter or manipulation of fruits, nuts, or carcasses. The process of foraging and feeding may take up a considerable portion of the animal's time[2].

In zoos and aquaria, by contrast, food is often much easier for animals to locate and process. It is common practice for zoological collections to chop their animal diets into small chunks and to place them in containers such as bowls or troughs[3][4] (Table 1). Feeding using a typical container format can result in minimal processing time, resulting in the animal having excess time to spare[5]. Other practices used by zoo professionals include enrichment feeds, scatter feeding, and burying items[2]. Some of the food presentation methods are believed to encourage animals to work for their food: these include impaled, scattered, or buried items[2][3]. Ideally, food presentation and preparation should be biologically relevant to the species in question[6].

Table 1. Food preparation and presentation styles used by zoos and aquariums.

Food Presentation Style	Description	Food types	Preparation/Presentation	Authors
Chopped items	Items are chopped into cubes of varying size (depending on the animal species and husbandry protocol).	Fruits, vegetables, carcasses, browse, and hay	Preparation	Plowman et al., Shora et a[3][4]
Whole food items	Food items are provided in their entire format. Skins and peels are not removed from the food. Food is sometimes used as a vehicle to administer medication.	Fruits, vegetables, carcasses, browse, and hay	Preparation	Plowman et al., Shora et al.[3][4]
Blended	Items are processed in a blender into a liquid format. Blended food is used for certain age groups (e.g., neonates) and species (e.g., anteaters (*Myrmecopaga tridactyla*)).	Fruits, vegetables, meats, nuts, seeds, and pellets	Preparation	Bhardwaj and Pandey[6]
In container	Food is placed in a bowl or trough.	Fruits, vegetables, meats, seeds, nuts, and pellets	Presentation	Hosey and Melfi[1]
Scatter feed	Food is thrown across enclosures or mixed into a substrate so that individual	Fruits, vegetables, meats, seeds,	Presentation	Plowman et al., Britt et al.[2][3]

	items take time to find and process. Scatter feeds are typically used with small food items (chopped foods or nuts and seeds).	nuts, and pellets		
Impaled	Enclosure furnishings such as spikes or branches are used to suspend food items. Whole food items are typically used.	Fruits, vegetables, and carcasses	Presentation	Young[7]
Puzzle feeder	Small food items are inserted into a puzzle feeder that requires problem solving or persistence to solve.	Fruits, vegetables, seeds, and pellets	Presentation	Field and Thomas[8]
Buried	Food items are hidden in substrates such as sand or soil.	Fruits, vegetables, meats, seeds, nuts, and pellets	Presentation	Young[7]
On enclosure roof	Larger food items are thrown onto exhibit mesh, requiring animals to climb and manipulate their meal.	Fruits, vegetables, meats, and pellets	Presentation	Britt et al.[2]

Many sources have identified the enrichment value in making food more difficult to obtain and process[1][9][3]. Some taxa, such as parrots, are willing to work for food and will even engage in contra-freeloading[8][10]. However, chopped food diets, which are much easier for animals to process, are still used in zoological collections[1]. This suggests that there may be reasons why meals are provided chopped.

Plowman et al.[3] used personal communication with zoo professionals to identify reasons why many zoo diets are chopped. Keepers suggested that chopped food would reduce group aggression, improve distribution of food, prolong feeding times, and prevent wastage (where animals take one bite and discard the remainder of the food). It has also been suggested that a chopped food diet is easier to manipulate for small animals, and a much greater diversity of food items can be offered when chopped (as opposed to just two or three whole fruits).

Similarly, concerns have also been raised about some food presentation methods. For example, buried, impaled, and scattered food may become contaminated by the environment, and food wastage is likely to be higher[11]. All of these methods require keepers to spend a much greater amount of time engaged in cleaning, and pest risks may be higher than in a typical container-fed situation.

These concerns, raised by animal keepers, may prevent some collections from moving toward more naturalistic food preparation and presentation methods. In order to move forward with evidence-based food presentation, studies are required to investigate these concerns.

2. Behavioral Impacts

The impacts of food preparation and presentation styles have been well studied for some taxonomic groups. Focusing specifically on food preparation techniques, studies are available from many animal-keeping sectors (Table 2). The fish and agricultural industries have conducted large-scale investigations into the effects of food particle size, with research often focusing on its effects on growth, body weight, and animal behavior[12][13][14][15][16]. Papers from zoological collections are also available, though some taxa (i.e., primates, *Macaca*) are better represented than others[11].

Table 2. Effects of food preparation on zoo animal behavior.

Order	Species	Preparation	Effects	Authors
Carnivora	Coati (*Nasua nasua)*	Chopped vs. whole	Reduced aggression when whole food was given. Increased food manipulation when whole food was given.	Shora et al. [4]
Primates	Barbary macaque (*Macaca sylvanus)*	Chopped vs. whole	Reduced aggression when whole food was provided. Increased grooming when whole food was provided.	Sandri et al. [17]

	Lion tailed macaque (*Macaca silenus)*	Chopped vs. whole	Total amount of food eaten increased when whole foods were provided. Dietary diversity increased when whole foods were provided.	Plowman[11]
	Rhesus macaque (*Macaca mulatta*)	Varying food particle size	Positive correlation was identified between food particle size and aggression.	Mathy and Isbell[18]
	Sulawesi macaque (*Macaca nigra)*	Chopped vs. whole	Subordinate ate significantly more food when whole food was provided. No other changes in behavior.	Plowman et al.[3]
Perissodactyla	Tapir (*Tapirus terrestris)*	Chopped vs. whole	Significantly less foraging when whole food was provided in clumps.	Plowman et al.[3]
Artiodactyla	Pig (*Sus scrofa)*	Effect of pellet size	Pigs spent significantly more time interacting with their troughs when larger pellets were given.	Edge et al.[14]
	Cattle (*Bos tauros)*	Chopped vs. long roughage	Calves preferred long hay to chopped hay. There was no preference when offered either long or chopped straw.	Webb et al.[12]
	Cattle (*Bos tauros*)	Chopped vs. long grass	Dry matter intake increased when short grass particle lengths were offered.	Kammes, and Allen[15]
	Cattle (*Bos	Chopped vs.	Hay intake was reduced when long	Couderc et

	tauros)	long hay	hay stalk lengths were provided.	al.[19]
	Sheep (*Ovis aries*)	Chopped vs. long silage	Sheep ate greater quantities of short stemmed silage.	Deswysen et al.[20]
	Sheep (*Ovis aries*)	Chopped vs. long grass	Dry matter intake increased when short, chopped kikuyu grass was offered.	Kenney et al.[16]
Psittaciformes	Orange winged Amazon parrots (*Amazona amazona)*	Effect of pellet size	Parrots showed significant preference for oversized pellets despite the food manipulation and chewing time increasing when large pellets were offered.	Rozek et al.[10]
Anguilliformes	European eel (*Anguilla anguilla)*	Effect of pellet size	No preference shown for smaller or larger pellets.	Knights[13]
Salmoniiformes	Salmon (*Salmo salar*)	Effect of pellet size	Large pellet sizes were more likely to be seized. Large pellets were more likely than small pellets to be rejected once they had been seized.	Smith and Metcalfe[21]
Clupeiformes	Pilchard (*Sardinops sagax*)	Effect of prey size	Pilchards showed preference for larger prey sizes.	Obaldo, and Masuda[22]
Decapoda	Southern brown shrimp (*Penaeus subtilis)*	Effect of pellet size	Shrimp showed preference for smaller pellet sizes. Shrimp were more successful at catching small pellets.	Nunes and Parsons[23]

	Pacific white shrimp (*Litopenaeus vannamei*)	Effect of pellet size	Shrimp were more likely to monopolize large pellets.	Obaldo and Masuda[22]

The effects of food preparation on behavior differ considerably between species. For primates, specifically macaques (*Macaca* spp.), the literature suggests that, when whole food items are provided, group aggression is reduced[17] while both food consumption[3][11] and allogrooming[17] increase. However, one paper identified a positive correlation between food particle size and aggression[18]. However, this study's method consisted of providing only a couple of food items at a time to a large group of macaques. This may have incited competition between individuals, as there was not enough food for all animals. Larger food items would have taken longer to eat and may have resulted in greater aggression.

Reduced aggression was seen in primates and coatis (*Nasua nasua*) (except in one study) when given whole food items[3][4][11][17]. This seems counterintuitive as larger food items should be of greater value[18]. However, animals often carried larger food items to a chosen feeding spot and spent longer engaged in feeding and food manipulation[4]. This may have reduced competition and monopolization over concentrated food resources, such as feeding containers[3].

Sheep (*Ovis aries*) and cattle (*Bos tauros*) are well studied in agricultural literature[15][16]. As grazers, discussions of chopped and whole foods are of limited biological relevance[15], so focus has been placed instead on the role of chopped or long grasses, hay, or silage[19][20]. Generally, both sheep and cattle ate more material when they were provided with chopped particles[20][15][16][19]. However, when given the choice between long and short stalks, one study found that calves chose long stalks[12]. This study, however, focused on preference rather than behavioral effects.

As ruminants, forage length plays an important role in rumen health and motility[19]. Smaller food items are fermented rapidly and, subsequently, process through the rumen faster than larger items[15]. Rumination is also less important as particle sizes are already much smaller[19]. The faster food transit time means that the animal can eat greater quantities of food during the same time period.

However, the faster digestion of smaller food particles by ruminal microbes also can result in acid by-products building up in the rumen, resulting in rumen acidosis[12]. Ruminants may therefore select longer stalks in order to counter acidotic ruminal conditions[15]. This is particularly important for animals fed high levels of concentrates or that are already experiencing rumen acidosis[12]. It is likely that similar trends in food preference may occur in zoo housed ruminants: research in this area would be beneficial.

This literature search identified no current evidence on food preparation effects for reptiles and amphibians. However, avian research is available that suggests that Amazon parrots (*Amazona amazona*) are more motivated to work for food when oversized pellets are provided, even though both pellets are of identical nutrition value[10]. For many parrot species, large food items may have some biological relevance, as they may mimic the natural diet of fruits and hard-bodied seeds. Feeding behaviors, such as chewing and gnawing, increased when the whole food items were provided[10].

Studies are available for both fish and invertebrates in food particle size. Much of this research has been conducted as part of aquaculture: as such, there is often a focus on feed conversion and efficiency rather than pure behavioral research[21]. For fish, patterns in pellet size research are not clear: both salmon (*Salmo salar*) and pilchards (*Sardinops sagax*) were more likely to select larger particles[21][22], yet no preference was seen for eels (*Anguilla anguilla*)[13]. It is likely that preferred particle size is related to the natural prey size of the species.

For shrimp, research suggests that small particle sizes are more appropriate, as both species were better able to capture and feed on smaller particles[23][22]. Shrimp were also more likely to monopolize larger particles, resulting in higher aggression[22].

Across all taxa, there is no clear consensus as to whether foods should be provided chopped or whole or in large or small pellets. However, there appear to be similar trends across closely related species. For example, whole fruit and vegetable items appear to be beneficial across primates and long-stem hay and straw have behavioral and physical benefits for many ruminants. It is possible that there is an underlying pattern with specific ecological niches either benefitting or being disadvantaged by whole foods. However, there are still major gaps in the food preparation literature: examples include many avian taxa, along with reptiles and amphibians. Research covering some of the current gaps may be valuable to better inform husbandry practices.

3. Nutritional Effects

In theory, food preparation should not affect the nutrient value of an animal meal if nothing has been added to the diet. However, common practices such as chopping can have profound effects on food nutrient value. Practices may affect the rate of desiccation, nutrient breakdown, color, and texture[24][25][26]. The nutritional consequences of diet preparation have not been explored fully in the zoo environment[3]; however, considerable research has been undertaken in the field of human food science[27].

In food science, the term “minimally processed” (MP) is used to describe fruits and vegetables that have been partly prepared for consumption[28]. Preparation typically involves peeling and cutting, though it may also include packaging and chemical treatment for antimicrobial purposes. Some of the MP fruit and vegetable research is of direct relevance to zoo researchers, as it evaluates the nutrient effects of preparation styles, such as when foods are sliced into 3-cm cubes[26].

Across the range of commonly fed fruit and vegetables, several changes occur consistently. In their raw form, fruits and vegetables still consist of living tissues. The metabolism of these tissues often increases when the fruit is cut, as this is the equivalent of tissue wounding[29]. Carbon dioxide production rapidly increases, as does the production of ethylene[26] (Table 3). These changes affect the nutrient value of the food, along with its color, texture, and taste[27]. These effects, which may not be pronounced immediately after food preparation, will become more pronounced the longer the time between food preparation and feeding[27][28].

Table 3. Effects of food preparation techniques on nutrient quality.

Preparation Type	Effect	Explanation	Food item	Authors
Chopping	Increased respiration	After slicing, carbon dioxide production increased.	Strawberry (*Fragaria ananassa*) and pear (*Pyrus communis)*	Brecht[28]
	Starch breakdown	Starch breakdown increased following cutting.	Tomato (*Lycopersicon esculentum),* mangoes (*Mangifera indica)*	Brecht and Sothornvit and Rodsamran[28][30]
	Ascorbic acid	Ascorbic acid (vitamin C content) reduced after cutting.	Squash (*Cucurbita moschata)*	Sasaki et al. [26]
	Ethylene production	Ethylene production rapidly increased shortly after cutting.	Squash (*Cucurbita moschata),* tomato (*Lycopersicon esculentum)*, cantaloupe melon (*Cucumis melo)*	Brecht, Sasaki et al. [26][28]
	Desiccation	Smaller particle sizes lost water moisture more rapidly.	Squash (*Cucurbita moschata)*	Sasaki et al. [26]

	All-E-β-carotene bioavailability	*All-E-β*-carotene was more bioavailable at smaller particle sizes.	Carrot (*Daucus carota*)	Lemmens et al.[27]
Blending	Ascorbic acid	Ascorbic acid levels were lower when drinks were prepared using blending.	Apple (*Malus domestica),* pear, (*Pyrus communis)*, mandarin orange (*Citrus reticulata)* and persimmon (*Diospyros kaki*)	Pyoet al, Castillejo et al.[31][32]
	Antioxidants	Antioxidant capacity decreased (in comparison to thermally treated smoothie samples)	Cucumber (*Cucumis sativus),* spinach (*Spinacia oleracea)*	Castillejo et al., Picouet et al.[32][33]

Desiccation of food is also associated with chopping of diets; smaller food pieces result in faster desiccation rates[28]. The surface area of chopped food items is much greater than that of the original item[24]. Furthermore, moist surfaces are exposed, which speeds loss of water[29]. Desiccation is also affected by environmental factors such as high temperatures, wind, and low humidity and by time since preparation.

Changes to fruit and vegetable color and texture are probably familiar to many keepers; these include browning, whitening, and softening[24]. Changes may affect how animals interact with their food items and are also indicative of changes in nutrient composition. Ethylene production is an example. Ethylene is an alkene that is responsible for accelerating both the ripening of fruit and senescence in plants[28][29], and its production peaks once produce is cut or wounded. In addition to ripening effects, ethylene causes other physiologic changes such as bitter tastes for carrots (*Daucus carota*)[27] and loss of color in leafy vegetables[28].

The ripening process also alters the carbohydrate composition of fruits[26]. The cut tissues begin to convert starches into simpler sugars, which results in a sweeter tasting food item, but a lower starch quantity[30]. Simple sugars are digested and absorbed quicker than complex carbohydrates such as starch[34][35]. This could result in animals having more pronounced peaks and troughs in blood sugar over the course of the day.

Other changes to nutrient quality occur, though these may be more dependent on the type of fruit or vegetable. For example, squash (*Cucurbita moschata*) ascorbic acid (Vitamin C) concentration tends to reduce following cutting[26].

Environmental temperature also affects food nutrient composition. The warmer the environment, the more rapidly that ethylene will be produced and that ascorbic acids and starches will denature[28]. This is important for zoological collections as many species are housed in tropical houses: the warm temperatures might speed the rate of food deterioration[25].

Knife quality and particle size also have an impact, with smaller particle sizes resulting in more rapid breakdown of starch, desiccation, and fruit metabolism[28]. This is taken to an extreme for items which have been blended. Very small particle sizes along with damaged plant cell walls[25] result in rapid changes in nutrient values. Sharp knives produce cleaner cuts, which damage fewer plant cells and therefore result in slower degradation of food nutrients[36].

The preparation of zoo and aquarium animal diets therefore poses some unexpected challenges. Any chopping or blending of diet components is likely to affect their nutrient composition. However, effects become more pronounced over time. Many nutritional studies investigated nutrient breakdown over the course of days or weeks[24][25][26]. By contrast, zoo diets are likely to be prepared and consumed within 24 hours. While diet nutritional effects may be not be excessive, in some scenarios, they could be quite pronounced.

For example, some collections make use of a centralized kitchen, in which diets for all animals are prepared, sometimes in advance of feeding[1]. Other collections may prepare chopped food diets the night before feeding in order to save time in the morning. In hot, humid conditions, diet components may also desiccate more rapidly.

4. Microbiological Effects

In nature, animal foodstuffs possess a microbiome of bacteria, fungi, protozoa, and viruses[37]. The outer skin or peel of fruits and vegetables may contain a wide range of microbes, and even the inner flesh may contain low numbers[26]. Plant microbiomes vary based on their host. For example, acidic fruits tend to harbor fungi and lactic acid bacteria, and bacteria are common on vegetables[37]. Similarly, animal by-products are often contaminated by microbes[3].

Ecologically, animals evolved defense mechanisms to cope with many of the microbes they encounter when feeding[37][38], and not all microbes are pathogenic to all species. However, the potential for contamination of foods in zoos and aquariums should be considered.

The microbial communities found in raw or minimally processed foods destined for human consumption are well documented[39][40]. Many of these contaminants would typically be eliminated during preparation methods such as washing, boiling, steaming, or peeling for human meals[26][39][40]. Animal diets are often prepared using similar techniques, and the food may originate from the same sources as human foods (such as supermarkets)[1]. Whilst it should be noted that some zoos accept food donations from supermarkets, where food may be nearing its sell-by-date, the food should still be relatively low in contaminants as a result of its processing[1]. The levels of contaminants found on many foods are unlikely to be sufficient to cause disease[26]. Many food preparation methods act as a source of contamination. For example, chopping of food can result in contamination of food if the equipment and surfaces are not sufficiently clean between meal preparations[41][42][43]. Chopping breaks down cell walls, releasing cell proteins for use by microbes[37]. The moist surfaces of chopped food particles also encourage bacterial growth, particularly in high-humidity, high-temperature environments[26]. In itself, the action of chopping diets may not increase bacterial load greatly. However, there may be a much greater risk if the diet is prepared the night before feeding, as this will provide microbes with time to reproduce. Similarly, the use of blenders, which are often difficult to clean, could result in bacterial inoculation of foods[44].

Some food presentation methods may also increase the chances of food contamination. For example, providing food in a scattered or buried format, particularly when food particles are chopped, will increase the likelihood that dirt and bacteria are consumed by the animal[42]. Similarly, impaling food items onto exhibit furnishings is likely to drive microbes into the food item and could increase chances of contamination.

Animals are able to withstand some level of microbiological contamination in their diet[45][46]. There may be major behavioral benefits from using some of the more creative methods for diet presentation that add value to the animal's welfare. More than avoiding all sources of contaminants, keepers should be aware of potential contamination risks that may affect the foods they feed and should put practices in place to reduce the impact of these.

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