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A synthetic diet for fruit-eating birds.—Long-term maintenance of fruit-eating birds has been a major barrier to their study in captivity. Recently captured birds lose weight rapidly, even when feeding on fruits ad libitum. Birds under 50 g may lose weight so rapidly that flight muscles are seriously weakened; death may occur within a few days of capture (Moermond, Denslow, and Levey, pers. obs.). Studies using recently captured birds in poor physiological condition are unlikely to yield consistent or interpretable results. It is therefore important that experimental animals be maintained at good nutritional and energetic levels before behavioral experiments are initiated.

In this paper we describe a synthetic diet for maintaining captive fruit-eating birds, with notes on its use. We have been able to keep 25 species of tropical and temperate fruit-eating birds on this diet at steady weight and in good plumage for periods of up to 12 months. Some of these birds were recaptured in good condition months after their release.

We have used captive fruit-eating birds maintained on this diet for a variety of behavioral studies (Moermond and Denslow 1983, 1985; Levey et al. 1984). The diet is not only useful for maintaining experimental birds but can be manipulated as an experimental tool.

The diet.—The synthetic diet consists primarily of a mixture of mashed ripe bananas, soy protein isolate, and a supplement of vitamins and minerals in an agar-based gel (Appendix 1).

A protein gelatin (i.e., Knox®) may be an acceptable substitute for agar where the latter is either too expensive or unavailable. An agar or gelatin base makes the diet easy to handle, insures a uniform composition of the mixture, and precludes selection of only the more palatable components of the mixture by the birds. At warm temperatures (>25°C) under which our birds were held, the food ferments quickly; we replaced it twice daily, at sunrise and at noon. A mold retardant such as ascorbic acid could be added to retard rapid deterioration, although we have not done so.

Habituation techniques.—The yellow-brown mash bears little resemblance to brightly-colored fruits frugivores normally eat, and is thus often not recognized as food by naive birds. Newly caught birds therefore must be habituated to the mixture after capture.

TABLE 1

NUTRIENT AND CALORIC CONTENT OF SYNTHETIC DIET FOR FRUIT-EATING BIRDS (VALUES ARE CALCULATED FROM PUBLISHED DATA ON THE COMPOSITION OF THE DIET CONSTITUENTS [WATT AND MURIEL 1963] AND DATA SUPPLIED WITH THE SOYBEAN PROTEIN ISOLATE [U.S. BIOCHEMICAL CORPORATION, CLEVELAND, OHIO 44128])

	g/100 g dry weight
Protein	16.3
Fat	5.0
Carbohydrates	73.6
Fiber	5.0
Calcium	0.18
Phosphorus	0.34
Iron	0.25
Sodium	0.20
Potassium	0.72
Water	86%
Energy content (Kcal)	425.7

We have had the most success inducing naive birds to eat the diet after it was cut into small cubes (3 × 3 × 3 mm) and colored with red or blue food coloring. Natural berry juices (e.g., Pokeberry [*Phytolacca* spp.]) can also be used to stain the gel. The cubes, thus simulating berries, should be presented with a few natural berries in a small dish near a perch. Most birds will eat the berries and then sample the colored cubes. More berries should be added if no cubes are eaten within 1–2 h. Once the bird has begun to eat colored cubes, these can be presented on top of similarly colored food that has been mashed or broken up with a fork. The number of cubes should be decreased gradually and embedded in the colored mash until the bird eats the mash. The amount of color added to the mash can then be reduced to several spots and, finally, eliminated. The entire process usually takes 4–7 days. All individuals we tested learned more quickly when caged with a conspecific already feeding on the diet. Captive Cedar Waxwings (*Bombycilla cedrorum*), Gray Catbirds (*Dumetella carolinensis*), and Swainson's Thrushes (*Catharus ustulatus*) ingested about twice their body weights in fresh food daily, although the exact amount varied among species and depended on such factors as protein content and ripeness of the bananas (Denslow and DeVito, unpubl. data).

Birds that take most of their fruits on the wing (e.g., Pipridae, Trogonidae, Tyrannidae) are the most difficult to habituate. These birds pluck and swallow whole fruits presented away from foliage (Moermond and Denslow 1985). We have always found it necessary to use brightly colored cubes of the gel when training such birds. Murphy and King (1982) also found that captive Cedar Waxwings, another sallying species, more readily ate an artificial diet if presented in berry-like lumps. In contrast, tanagers are relatively easy to train, readily accepting the diet. We have been able to start them on the diet simply by placing fruits on top of and mixed with mashed colored gel.

Nutritional, caloric, and water contents of the diet (Table 1) fall within the ranges of those reported from natural fruits (Stiles 1980, Wheelwright et al. 1984). In comparison with fruits from the 29 tropical plant families surveyed by Moermond and Denslow (1985), the banana

TABLE 2

SPECIES OF FRUIT-EATING BIRDS MAINTAINED SUCCESSFULLY ON THE ARTIFICIAL DIET, AND THE EASE WITH WHICH THEY WERE KEPT

Species	Ease of maintenance[a]
Slaty-tailed Trogon (*Trogon massena*)	++
Collared Araçari (*Pteroglossus torquatus*)	+++
Ochre-bellied Flycatcher (*Mionectes oleagineus*)	+
Gray-capped Flycatcher (*Myiozetetes granadensis*)	+
White-ruffed Manakin (*Corapipo altera*)	++++
White-collared Manakin (*Manacus candei*)	++++
Red-capped Manakin (*Pipra mentalis*)	++++
Swainson's Thrush (*Catharus ustulatus*)	+++
Wood Thrush (*Hylocichla mustelina*)	+++
Pale-vented Thrush (*Turdus obsoletus*)	+++
Gray Catbird (*Dumetella carolinensis*)	+++
Cedar Waxwing (*Bombycilla cedrorum*)	++++
Scrub Euphonia (*Euphonia affinis*)	++++
Olive-backed Euphonia (*E. gouldi*)	++++
Red-throated Ant-Tanager (*Habia fuscicauda*)	+++
Dusky-faced Tanager (*Mitrospingus cassinii*)	+
Scarlet-rumped Tanager (*Ramphocelus passerinii*)	++++
Tawny-crested Tanager (*Tachyphonus delatrii*)	+
Plain-colored Tanager (*Tangara inornata*)	+++
Golden-masked Tanager (*T. larvata*)	+++
Blue-gray Tanager (*Thraupis episcopus*)	+++
Palm Tanager (*T. palmarum*)	++++
Black-faced Grosbeak (*Caryothraustes poliogaster*)	+
Buff-throated Saltator (*Saltator maximus*)	++
Orange-billed Sparrow (*Arremon aurantiirostris*)	+

[a] + = Accepted diet after 7 days, but weight fluctuated widely. We found it necessary to supplement the diet with insects. Adjusted well to captivity and behavioral experiments. ++ = Accepted diet (usually in 7 days) and maintained capture weight, but did not adjust well to captivity or behavioral experiments. +++ = Accepted diet in 7 days, maintained capture weight, and adjusted well to captivity and behavioral experiments. ++++ = Accepted diet within 3 days, maintained weight, and adjusted well to captivity and behavioral experiments.

diet is rich in proteins and carbohydrates and low in lipids. The median protein content was 8.4% (dry weight) for 29 families of tropical fruits in the survey compared to approximately 16.3% in the synthetic diet. Although it is likely that fruit-eating birds depend on fruits primarily as an energy source and supplement the fruit component of their diets with insects (Moermond and Denslow 1985), species vary widely in their dependence on nonfruit protein sources. The diet is therefore not equally suitable for maintaining all species of fruit-eating birds (Table 2). We have had difficulty maintaining some frugivorous finches (e.g., emberizids such as *Caryothraustes poliogaster, Cyanocompsa cyanoides*), some species of tanagers (e.g., *Tachyphonus* spp. and *Mitrospingus cassinii*), and frugivorous flycatchers (e.g., *Myiozetetes* spp. and *Mionectes* spp.). Although all these species commonly feed on fruit in the field (Jenkins 1969, Fitzpatrick 1980), they were maintained successfully in cages only by supplementing the synthetic diet with live insects. Alternatively, the protein content of

the diet could be increased slightly (although increased addition of the soy isolate makes the texture unacceptable for some birds).

Maintenance of captive birds.—We suggest that each bird's weight be followed closely, at least until weight has stabilized and the bird is fully habituated to the diet. Remote weighing devices eliminate trauma to the bird while it is being weighed. After an initial slight loss of weight, birds usually regained capture weight within 2 weeks. Weights of captive birds kept on this diet have generally fluctuated within 5% of capture weight.

Two sources of water should be provided: a tube for drinking and a dish for bathing (the latter is critical for maintenance of healthy plumage). Birds can often be induced to bathe if sprayed with a fine mist of water and learn quickly if in a position to observe other birds bathing.

If the birds are to be kept outside, care should be taken to provide adequate shade and protection from wind, rain, and predators. In Costa Rica, ants (*Solenopsis* sp.), bees (*Trigona* sp.), rats (*Rattus* sp.), and snakes (Boa constrictor, *Pseustes poecilonotus*) were constant problems. Ants and bees feed on the gel, preventing the birds from feeding. Ants can be controlled with Tanglefoot® on all points of access to the cages. Sturdy, tightly sealed cages are the best protection against bees and predators.

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APPENDIX 1

Ingredients for approximately 2 l of food:

1 l water
11 g agar (approximately)
1.5 g sodium chloride
1.6 g dicalcium phosphate
1.5 g complete vitamin and mineral supplement for birds[1]
25 g soy protein isolate
7 g vegetable oil
37 g wheat germ
680 g mashed bananas, fully ripe

Directions:

Carefully stir agar into rapidly boiling water, preferably with a whisk, continuing to stir until water comes again to a rolling boil and the agar is completely dissolved. If the agar does not dissolve, the food will not "set" firmly. In a separate dish, mix the soy isolate with a small amount of water to make a paste. Thoroughly stir the paste and remaining ingredients into the mashed bananas. Add the agar solution and mix well. Check the sugar concentration with a refractometer and, if necessary, bring the mixture up to approximately 10% with glucose. Place in covered containers and refrigerate. The appropriate amount of agar varies depending upon the brand and purity. The mixture should congeal at room temperature, but also should be easily mashed with a fork. It will keep for approximately one week under refrigeration, but may also be frozen. The texture of thawed gel is much less cohesive but still adequate as a maintenance diet. Only fully ripe bananas should be used because all birds prefer them over slightly unripe bananas, which are poorly assimilated.

[1] We have used 8in1® Vitamin Mineral Supplement for Birds, made by 8in1 Pet Products, Inc., Brentwood, New York 11717.

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Bathing behavior of nesting Prairie Falcons (*Falco mexicanus*) in southwestern Idaho.—During 1984 and 1985 we observed 24 Prairie Falcon pairs nesting in the Snake River Birds of Prey Area (BOPA), in southwestern Idaho, from egg laying and incubation through brood rearing until the chicks were 35 days of age (a total of about 4400 h of observation). During this period we recorded 34 dustbaths: 4 were taken by males (3 different individuals) and 30 by females (8 different individuals). All dustbaths were taken on sections of cliffs where a layer of sandstone was exposed and a ledge was available. The falcons landed on these ledges and shuffled on their abdomens through the fine sand with the body feathers fluffed out and their wing and tail feathers partly extended. Dustbathing birds frequently made dipping motions with their heads and bodies. Dustbathing was followed by extensive preening of breast, wing, and tail feathers, and, finally, by shaking of the entire body. Dustbathing averaged 4.7 ± 5.7 min [SD] (range = 1–13 min, N = 4) for males and 2.1 ± 1.6 min (range = 1–6 min, N = 30) for females. Three incubating females took up to 3 dustbaths a day. The aerie of one incubating female who took regular dust baths in 1984 was heavily infested with swallow bedbugs (*Oeciacus vicarius*). The aerie was a large cave, and the chicks (4 of which fledged) probably were able to move away from the source of infestation.

On 28 May 1985 we saw a female Prairie Falcon drink water and take a bath in a depression in a rock, where water had collected after a rainstorm the previous day. Bent (U.S. Natl. Mus. Bull. 167:18–22, 1938) considered water bathing by Prairie Falcons a rare event. Captive Prairie Falcons, however, preferred water baths above dustbaths when both were provided (B. A. Haak, unpubl. data). The general scarcity of standing water in areas inhabited by Prairie Falcons may force them to take dustbaths, but apparently they prefer to bathe in suitable pools or puddles when available.

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