SHORT COMMUNICATIONS

Semi-synthetic Diets as a Tool for Nutritional Ecology

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Growing interest in the potential role of specific nutrients (e.g. amino acids) as limiting factors in growth (Morton 1973, Ricklefs 1976), reproduction (Jones and Ward 1976, 1979; Raveling 1979, Fogden and Fogden 1979), and feather synthesis (Hanson 1962, Newton 1968, Ward 1969, Gavrilov and Dolnik 1974) heralds the onset of a trend that might be called "nutritional ecology." In attempting to understand the demands of these processes in wild species, a knowledge of nutrient requirements is imperative. Unfortunately, the requirements of free-living species of birds are essentially unknown (Fisher 1972) and potentially differ significantly from those of domestic species that have been inbred for improvement of meat and egg production. Identification of the nutritional needs of wild birds, and the subsequent clarification of the apparent enigmas of nutrient requirements and supply, is hindered by the overwhelming chore of detailed compositional analysis of naturally occurring foods. Determination of the dietary requirements of an organism requires an exact knowledge, and control, of the availability of a nutrient, in the face of the constancy and adequacy of other essential and indispensable dietary components. Furthermore, for comparative studies it is desirable to replicate dietary composition accurately.

Several difficulties are encountered when attempting to meet these criteria with diets compounded of raw foodstuffs. Poultry nutritionists, among others, have circumvented these problems by the use of defined, semi-synthetic diets. Application of this practice to the study of the nutrient requirements of wild birds can provide not only basic reference standards, but also avert some laborious and expensive analyses currently required to characterize natural diets. This report describes the successful use of a semi-synthetic diet in extensive tests with four granivorous species and in a brief trial with a frugivore.

We used a modified version (Tables 1 and 2) of the Illinois crystalline amino acid diet (Baker et al. 1979). In all tests the birds were housed in individual cages (22 × 40 × 27 cm) in a constant-condition room (21°C, LD 16:8) and provided with water *ad libitum*. In the first test we transferred 12 House Sparrows (*Passer domesticus*) that were in the midst of postnuptial molt from a ration of granular chick-starter mash to the semi-synthetic ration. For the next 28 days we measured body weight and noted the state of molt at 4-day intervals. In all cases, body weight varied no more than 1 g from weights recorded while the birds were eating chick-starter mash, and likewise did not differ significantly from the weights in a control group fed chick-starter mash through the same period of time. Furthermore, both the pattern and rate of feather growth (as judged from measurements of primary and secondary remiges) were unaffected by the transition to the semi-synthetic diet.

A second test involved 36 White-crowned Sparrows (*Zonotrichia leucophrys gambelii*) that had been subjected for other purposes to experimental photoregimes that eventually induced the analogs of either postnuptial molt or of prenuptial molt followed by premigratory fattening. Initially, all birds were fed the granular chick-starter mash. After this, 8 nonmolting birds were provided one hopper of the powdered semi-synthetic diet and one of chick-starter mash for 1 week, followed by feeding of the semi-synthetic diet alone. The remaining 28 birds had access to one food hopper containing chick-starter mash, one containing the semi-synthetic diet in powdered form, and one containing "seeds" (diameter, 2 mm) made from the semi-synthetic diet. We made the "seeds" by mixing equal quantities of the semi-synthetic diet (after compensatory changes in the celufil content) with a 3% agar solution. This makes a dough-like mixture that can be squeezed from a syringe or a pastry press into strips that can be cut and rolled into seed-like shapes. To minimize dessication, these must be refrigerated in air-tight containers. By the end of a week of access to the three choices just described, the birds showed a uniform and clear-cut preference: "seeds" > powder > chick-starter mash. This order of preference persisted for the remaining 3 weeks of the test. The "seed" hopper was always emptied first. This is readily understandable in a species that is adapted to consuming discrete packets of food, but the clear-cut secondary preference for the powdery semi-synthetic ration over the more granular chick-starter mash was unexpected. This may implicate aspects of palatability or appetite for specific nutrients that merit further investigation.

The eight White-crowned Sparrows that had been eating the powdery semi-synthetic ration alone were retained for further observation. As a result of their differing photoperiodic history, 4 of these birds underwent a postnuptial-like molt 3 weeks after the beginning of the test, and 4 underwent a prenuptial-like molt followed by premigratory fattening. The progress and intensity of these events were essentially identical to those found previously in birds

TABLE 1. Composition of the complete semi-synthetic diet.

Basal diet	%
Casein[a]	10.00
Amino acid mixture (see Table 2)	2.77
Salt mixture[b]	5.50
H_3BO_3	0.0009
$Na_2MoO_4 \cdot 2H_2O$	0.0009
$CoSO_4 \cdot 7H_2O$	0.0001
Na_2SeO_3	0.00002
$NaHCO_3$	1.00
Choline chloride	0.20
Vegetable oil	7.00
Cod liver oil	1.00
Cellulose[c]	5.00
Ground silica sand	5.00
Vitamin mix[d]	+
Corn starch	to 100.00

[a] Casein (High Nitrogen), United States Biochemical Corporation, Cleveland, Ohio.
[b] Salt mixture Fox-Briggs, United States Biochemical Corporation, Cleveland, Ohio.
[c] Celufil-Hydrolyzed, United States Biochemical Corporation, Cleveland, Ohio.
[d] Vitamin Diet Supplements (vitamin D_3 substituted for D_2), United States Biochemical Corporation, Cleveland, Ohio. Added to the diet at a rate of 1 kg vitamin supplements to 100 lb of diet.

TABLE 2. Amino acid composition of the complete semi-synthetic diet.

	% diet	
Amino acid	Crystalline amino acid[a]	Total[b]
Alanine	—	0.22
Arginine	0.79	1.10
Aspartic acid	—	0.54
Cystine	0.32	0.35
Glycine	0.36	0.57
Glutamic acid	—	1.72
Histidine	0.18	0.41
Isoleucine	0.06	0.52
Leucine	0.18	0.89
Lysine	0.41	1.04
Methionine	0.10	0.31
Phenylalanine	0.06	0.40
Proline	—	0.86
Serine	—	0.48
Threonine	0.22	0.59
Tryptophan	0.04	0.13
Tyrosine	—	0.48
Valine	0.05	0.60

[a] All crystalline amino acids were the L-isomer. Arg, his, and lys were in the hydrochloride form. L-leucine was met free. L-threonine was allo free.
[b] Including casein, based on USB compositional analysis of High Nitrogen Casein.

subsisting on chick-starter mash (King and Farner 1965, Chilgren 1975) or a natural diet in the field (King et al. 1963). At the time this report was written these birds had remained in good health after 6 months on the semi-synthetic diet.

Briefer trials were conducted with Savannah Sparrows (*Passerculus sandwichensis*), Gray-crowned Rosy Finches (*Leucosticte tephrocotis*), and a single Cedar Waxwing (*Bombycilla cedrorum*), all yielding results similar to those already mentioned. Four Savannah Sparrows captured during spring migration (April) immediately accepted the powdered semi-synthetic ration and maintained migratory fat reserves. These reserves diminished to a nonmigratory level by late May, and the birds initiated a postnuptial molt in early July. The molt progressed in the typical passerine sequence and the birds maintained body weights in the range typical of free-living *P. s. nevadensis* (records from the Charles R. Conner Museum).

Four nonmolting Gray-crowned Rosy Finches were transferred from an outdoor aviary colony to indoor cages in June. They adapted immediately to the powdered semi-synthetic diet and maintained body weights typical of free-living individuals (King and Wales 1965). In early July they initiated a postnuptial molt that proceeded in the normal pattern.

Finally, a brief (10-day) test with a Cedar Waxwing showed that this bird will consume larger berry-like versions of the dough-mix ration. It seemed particularly important for this species that the "berries" be moist and pliable, as might be expected of a species adapted to frugivory.

In sum, we have shown that four species of granivores will accept (or prefer) a semi-synthetic ration and will undergo normal physiological cycles while subsisting on it. More limited data from a frugivore suggest that semi-synthetic rations may be serviceable for experiments with this group as well. Presentation of the pelleted ration ("seeds" and "fruits") may be useful in promoting acceptance of the semi-synthetic ration in some species, and is also important in reducing per diem costs by minimizing spillage. The per diem cost of the semi-synthetic diet used in these experiments, for a 27-g sparrow, is 3¢ (allowing for normal spillage), but this will vary substantially with the design of the diet. For example, cost may more than double if all amino acids are supplied in the crystalline form.

Although nutrient requirements will vary to some extent with dietary composition (e.g. protein level), the plasticity of semi-synthetic diets allows for formulation of any permutation desired. For instance, protein and amino acid content may be adjusted to approximate that of plants, animals, or combinations of the two.

We have used amino acid requirements as our main examples in this report, but the usefulness of semi-synthetic diets extends to all classes of nutrients. Moreover, such diets may be useful in studies beyond the formal scope of nutrition, such as the hand-rearing of nestlings or behavioral investigations of the dietary elements involved in food preference.

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First Record of the Great Auk (*Pinguinus impennis*) from Labrador

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Recent archeological investigations undertaken by Bryn Mawr College and the Smithsonian Institution along the Torngat Mountain coastline of northernmost Labrador have produced the first documented evidence of the extinct Great Auk, *Pinguinus impennis*, from the Labrador Peninsula. Avayalik Island, where the Great Auk remains were recovered, is only 25 km south of the northern tip of the peninsula (60°06′30″N; 64°13′10″W). The bones were excavated from a site denominated Avayalik-1 (Jordan 1980), located on a small and barren outer island that was occupied by Dorset Paleo-Eskimos between 400 and 450 A.D. Frozen midden deposits at this site contain hunting, butchering, and processing tools, domestic utensils, debris from tool manufacturing, faunal remains, and occasional amulets and ritual objects usually associated with hunting magic (Jordan 1979–80). The Eskimos here depended heavily upon marine mammals and seabirds for food. Of 1,700 mammal bones identified, over 90% are from seals and walrus. About 1,300 specimens of birds are approximately evenly divided among large gulls (Laridae), diving ducks (Anatidae), shearwaters (Procellariidae), and alcids (Alcidae). A few remains of ravens, geese, small gulls, and ptarmigan were also recovered. The degree of maturity and composition of