Nutrient Composition of Locally Obtained Native Fishes (St. Catherines Island, GA, USA) Compared with Fish Commonly Purchased for North American Zoo Feeding Programs

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Nine species of local fishes, obtained as part of a larger population study, were chemically analyzed to determine nutrient composition prior to use in feeding programs at the Wildlife Survival Center, St. Catherines Island, Georgia, USA. The nutrient composition of locally obtainable fishes was compared to that of fishes commonly used in North American zoo feeding programs. The 9 local fish species analyzed in this study included bumper (*Chloroscombrus chrysurus*), striped anchovy (*Anchoa hepsetus*), striped mullet (*Mugil cephalus*), inland silverside (*Menidia beryllina*), pompano (*Trachinotus carolinus*), star drum (*Stellifer lanceolatus*), and striped killifish (*Fundulus majalis*). Fish sampling was conducted over a period of 19 months (September 1997 - March 1999). Assays performed included proximate composition (water, crude protein, crude fat, and ash), fat-soluble vitamins A and E, and minerals (Ca, Mg, Na, P, K, Cu, Fe, Mn, Zn, Co, Cr, and Mo). Results from local fishes were compared to summaries of the nutrient compositions of 6 fish species used regularly in feeding programs of the Wildlife Conservation Society. These 6 species included whitebait (*Allosmerus elongatus*), capelin (*Mallatus villosus*), spearing (*Menidia menidia*), herring (*Clupea harengus*), mackerel (*Scomberomorus scrombrus*), and trout (*Salmo gairdneri*). Results indicated that local fishes were similar to commonly used commercial fishes in water (68-79% and 72-80%, respectively) and protein (56-73% and 53-69%, respectively), but higher in ash (19-37% and 9-12%, respectively). Fat content in the local fishes was considerably lower than that commonly found in commercially available fishes used in zoo and aquarium feeding programs (7-16% and 19-35%, respectively). Vitamin E of the local fishes ranged from 46 IU/kg to 738 IU/kg (dry matter basis), whereas vitamin A of the local fishes ranged from 5170 IU/kg to 103,130 IU/kg. These values indicate that local fishes, although lower in vitamin A than commercial fish species, probably provide adequate vitamin A to piscivorous species without the need for external supplementation. However, additional vitamin E supplementation may be required for some fish species, both local and commercial. Data on the chemical composition of locally-available foodstuffs is not only essential for improving the nutritional evaluation of zoo diets, but also may have economic impacts on feeding programs due to food availability and improved animal health. Key words: piscivores, whole prey

INTRODUCTION

The number of fish species utilized for zoo feeding programs is limited, and may not be representative of the range of nutrients available to piscivorous carnivores. Although considerable research has been conducted on the nutrient composition of fish and fish products for human consumption [Sidwell, 1981], and numerous individual studies document body composition of whole fish, few publications summarize the chemical analysis of whole fish commonly consumed by piscivores in zoos and aquariums [see for example, Dierenfeld et al., 1991; Bernard and Allen, 1997].

Availability of commercial fish is typically based on seasonal catch. Thus, the feeding of piscivorous species in captivity is very dependent on frozen fish. Improper freezing and storage may lead to loss of nutritional quality, including the degradation of protein and destruction of available vitamins [Bernard and Ullery, 1989; Dierenfeld et al., 1991]. Utilizing locally obtained fish could decrease storage time, and thus possibly provide a fish of higher nutritional quality.

This investigation was conducted: 1) to increase information available on the nutrient content of whole fish; 2) to examine seasonal changes in nutrient composition of fish in a natural ecosystem, and; 3) to investigate possible economical and nutritional advantages of utilizing locally-acquired fishes compared with commercial sources in a captive feeding program.

MATERIALS AND METHODS

Collection of Specimens

Fish samples utilized in this study were obtained as part of a larger fish population study conducted off the coast of St. Catherines Island (SCI), Georgia, USA by the Department of Biology, Augusta State University, Georgia, USA. Fish populations were monitored by harvesting monthly to obtain information on the population size, density, and reproduction of local fish species in the area. From these monthly samplings, 1-2 kg of each fish species was kept frozen (maximum 0° C), no longer than 3 months, prior to analysis conducted by the Nutrition Department at the Bronx Zoo.

Preparation of Specimens

Frozen samples were partially thawed at room temperature prior to analysis. Whole specimens were weighed and measured, then ground using a small food processor. Vitamin assays were performed immediately after extraction (see below). Remaining sub-samples were freeze-dried and ground using a laboratory mill prior to proximate analyses.

Proximate Composition

Percent moisture, ash, crude fat, and crude protein were obtained using AOAC methodology for meat [Ellis, 1984]. Duplicate samples of freshly-ground fish (> 0.5 g) were weighed, freeze-dried, and percent moisture was calculated. These samples were then incinerated in a muffle furnace at 550° C overnight and total ash was calculated. Crude fat was determined by extraction with petroleum ether. Crude protein was determined by a Kjeldahl procedure with a copper catalyst, measured as total nitrogen (N) multiplied by 6.25.

Fat-Soluble Vitamins

Duplicate tissue samples (> 0.5 g) were homogenized with 5 ml of 2 mMol EDTA and 1 ml of 25% sodium ascorbate solution. The samples were mixed with 4 ml of 95% ethanol and 1 ml of 50% KOH. The mixtures were saponified in a 70° C water bath for 15 minutes, then cooled in an ice bath. Fat-soluble vitamins were extracted with 1 ml hexane containing 0.2% BHT, and a 1 ml aliquot of the hexane layer was evaporated under nitrogen. Saponification, extraction, and evaporation procedures were performed under yellow light. Samples were then reconstituted with 0.25 ml ethanol containing 0.1 % BHT. A Perkin Elmer (PE) series 400 liquid chromatograph equipped with a 15 cm C-18 reversed-phase column was used to quantify α-, and γ- tocopherols, and retinol as measures of vitamin E and A, respectively. The mobile phase was 96:4 methanol:water for tocopherol detection, and 90:10 methanol:water for retinol separation at a flow rate of 2 ml/min. Tocopherols were measured with a PE LS-1 fluorescence detector (excitation wavelength = 280 nm; emission wavelength> 310 nm) and retinol was monitored at 325 nm on a PE model LC-95 spectrophotometer [Taylor et al., 1976]. External standards were compared to sample extracts for determination of vitamin concentrations. Vitamin E activity was calculated as 1 mg α-tocopherol = 1.49 IU; 1mg γ-tocopherol = 0.15 IU [Horwitt, 1993]. Vitamin A activity was calculated as 0.3 μg retinol = 1 IU [Olson, 1984].

Elemental Composition

Mineral analysis was conducted on dried tissue samples, following standardized methods for inductively coupled plasma argon emission spectroscopy (ICP-AES) [Stahr, 1991].

Statistical Analyses and Comparisons to Commercially Available Fishes

Data are reported as means and standard deviation. Information on the six commonly used, commercially available fishes was obtained from the Nutrient Summary and Protocol Handbook [Wildlife Conservation Society, 1997].

RESULTS

Proximate Composition

The nine species of local fishes analyzed in this study showed wide variability in proximate composition. However, the values for both water and protein composition in the local fish were comparable to the range of data obtained from six commercially-available species (Table 1). Values for ash composition in the local fish were substantially above the ranges found in commercial fish. Fat composition in the local fish ranged well below that of commercial fish.

Fat-Soluble Vitamins

The range of values for vitamin E content in local fishes was comparable to those found in commercially available fish (Table 2). The striped killifish appears to be an exception with 738.2 IU/kg. This quantity, which exceeds that seen in all other fish analyzed, may be suspect given the small sample size (n=1) for this local species.

The range of values for vitamin A content was substantially higher in commercial fish than in fishes harvested locally (Table 2). The local southern kingfish and bay anchovy had vitamin A values well below those found in all other fish analyzed. Star drum was the exception to the general pattern, with 103,130.0 IU/kg vitamin A, a value higher than that found in almost all commercial fish assessed. Again the small sample size (n=1) may be a factor in this unusual value. On an individual basis, many locally available species were comparable in vitamin A content to commercially obtained fish. For example, inland silverside and striped killifish would be suitable substitutes for commercial trout, while pompano shows vitamin levels within the range of commercial capelin, spearing and herring.

Minerals

Macrominerals are listed in Table 3, whereas trace element concentrations are found in Table 4. Overall, Ca and P content of native fishes were higher than in commercially available species, although all fish analyzed showed a suitable Ca:P ratio. Magnesium and Na content were similar between the two groups of fish, but Mg content in the commercially available species seemed more variable compared with native fishes in this study. Sodium showed similar variability between native and commercially obtained fish species.

Of the trace minerals summarized, Cu and Zn levels were similar among both local and commercial fish, whereas Fe and Mn concentrations were considerably higher in SCI fishes. Small sample size may contribute to the wide variation (and high overall means) observed, particularly concerning values for Fe.

Seasonal Variation

Due to insufficient sample sizes in this study, the effects of seasonal variation on nutrient composition could not be assessed.

DISCUSSION

Captive piscivorous birds should be provided with a varied diet to minimize the possibilities of nutritional deficiencies and to avoid the development of preferences for one type of fish, the availability of which may vary with the commercial fish market [Stoskopf, 1983]. This study demonstrates that locally acquired native fishes near St. Catherines Island, GA may provide adequate substitutes for commercially obtained fish or may be used to supplement a diet of commercial fish. Locally harvested fish may prove advantageous to a zoo or conservation center in that this food source may lessen dependence on commercial fish suppliers, and may provide a source of readily available dietary variation and enrichment for sea birds. Yet it is critical to evaluate the nutritional composition of local fishes before incorporating them into a captive feeding program.

Protein and water content of native Georgia coast fishes was comparable to that of commonly used commercial fish. However, most of the local fishes analyzed had more ash, less fat and less vitamin A overall than the commercial fish evaluated in this and other studies [Bernard and Ullrey, 1989; Dierenfeld et al., 1991]. Thus, native fishes may provide less energy and nutrients than the commercial fish currently offered to piscivorous birds at the SCI Wildlife Survival Center (WCS).

The fat content of fish may be the most critical element in the nutrition of some, and possibly all piscivorous birds [Stoskopf, 1983]. Lipid content in fish may show considerable seasonal variation [Cruickshank, 1962; Stoskopf, 1983], and thus the findings of this study should be interpreted with caution, as a full range of seasons was not represented in the fish harvests. Many of the local harvests used in this study represented fall and winter catches when fat content in fish is typically lower.

The lower fat content of many of the local fish used in this study does not reduce their usefulness in a captive feeding program. It is often desirable to use low fat food items as enrichment, to insure that the bulk of the calories provided to collection animals are obtained from the prescribed diet rather than from rich "treat" items. Moreover, as obesity is a common plight of captive wild animals, a low fat fish may provide a much-needed substitute for the commercial fish commonly available.

Vitamin A values in the local fish were considerably lower than those reported for commercial fish, yet were higher than minimum concentrations (approximately 3000 to 15000 IU/kg dry matter (DM)) recommended for domestic poultry and carnivore species [Robbins, 1983]. Fat concentration and vitamin A levels may of course be correlated, so fish harvested in the fall and winter may show both lower fat content and correspondingly lower levels of fat soluble vitamins. Moreover, vitamin A accumulates in the liver of fish with increasing age, so older and larger fish are expected to have more vitamin A [Cruickshank, 1962]. Given that commercial fish tend to be larger than those harvested locally, the higher vitamin A content of commercial fish may simply reflect a size difference in the species considered for analysis.

Vitamin E levels in the locally harvested fish were comparable to those obtained from commercial fish. Thus any supplementation procedures used in the current diet should be continued when local fish are added to the diet, and appears to be necessary if attempting to meet recommendations of vitamin E in piscivore diets (400 IU/kg DM) [Dierenfeld et al., 1991].

Macrominerals in both the local and commercially available fishes appear adequate for a captive feeding program, if requirements for domestic poultry and carnivores can be extrapolated to the avian species fed here. Ca content of whole fish meet requirements that have been established for egg production (2.25 to 2.75% of dry matter) [NRC, 1984]. The small size of the native fishes collected may have contributed to the high calcium levels observed, reflecting a higher proportion of bone in the fish compared with larger species. Sodium content of whole marine fish, for all species analyzed, met known requirements providing fish are not thawed in fresh water.

Trace element content of both native and commercially available fish species appeared somewhat imbalanced with respect to known nutrient requirements of domestic poultry and carnivores. Cu, for example, may be marginal in these fish [reqt. 5 to 8 μg/g DM; NRC, 1984]. The commercial fishes appear adequate in dietary Fe [reqt. 60 to 1000 μg/g; NRC, 1984], but some of the native fishes were very high in Fe. Perhaps this indicates environmental variables (water quality, substrate, etc.); however, the low sample size makes interpretation of these data preliminary. Mn content of all fish may be low compared with requirements for growth in domestic poultry [40 to 90 μg/g; NRC, 1984]. Zn content of both native and commercial fishes appears adequate. Specific mineral requirements for non-domestic species have not been determined.

Locally harvested fish species can be successfully incorporated into the feeding regimen of piscivorous birds in a zoo or conservation center. All native fish used in this study were considered palatable to both milky storks (*Mycteria cinerea*) and saddle-billed storks (*Ephippiorhynchus sengegale*) at SCIWCS. The use of locally available fish can limit the amount of storage time between catch and consumption, thus decreasing the chance of lost nutrients. Minimal protein denaturation occurs in fish frozen rapidly at suitably low temperatures (i.e. below –30 °C) [Dyer and Dingle, 1962; Geiger and Borgstrom, 1962; Stoskopf, 1983], however, lipid peroxidation and vitamin oxidization is likely to occur with inadequate or prolonged freezing and thawing [Stoskopf, 1983]. Thus, the availability of local fish, which can be harvested and immediately added to diets, may provide a healthier substitute for commercial fish, which must often be bought in bulk and stored for long duration. The incorporation of native fishes in the diets of piscivorous birds would have the further advantage of reducing a facility's dependence on commercial fish providers, while providing much needed variation and enrichment in the diets of these valuable birds.

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Table 1. Proximate nutrient composition of wild-caught fish obtained near St. Catherines Island, GA and commercial fish species utilized in feeding programs at the Wildlife Conservation Society, Bronx, NY. All data (except water) presented on a percent dry matter basis.

SCI FISH

Fish	Statistic	Water	Ash	Fat	Protein
Bumper	mean	77.44	26.02	10.52	72.99
n=2	SD	0.68	3.92	0.89	4.84
Striped Anchovy	mean	79.53	18.75	10.02	72.88
n=1	SD				
Southern Kingfish	mean	75.88	30.18	6.60	63.26
n=2	SD	2.33	11.22	2.08	13.90
Bay Anchovy	mean	75.62	33.16	10.95	56.37
n=6	SD	6.33	18.26	3.04	15.23
Striped Mullet	mean	71.31	23.45	16.00	58.04
n=3	SD	5.91	6.83	7.23	5.45
Inland Silverside	mean	73.77	24.78	9.51	64.29
n=7	SD	2.38	5.85	2.51	2.01
Pompano	mean	76.10	28.89	10.02	69.03
n=2	SD	0.24	0.86	0.89	3.05
Star Drum	mean	75.22	37.35	12.52	55.67
n=1	SD				
Striped Killifish	mean	68.12	27.11	11.10	58.45
n=1	SD				
RANGES		**68-79%**	**19-37%**	**7-16%**	**56-73%**

COMMERCIAL FISH

Fish	Statistic	Water	Ash	Fat	Protein
Whitebait	mean	79.08	10.78	18.61	68.7
n=6	SD	3.3	1.8	6.84	8.74
Capelin	mean	79.85	10.01	19.11	67.31
n=45	SD	2.2	2.08	7.16	6.54
Spearing	mean	74.25	12.16	22.9	62.73
n=7	SD	2.71	2.56	4.89	9.04
Herring	mean	71.82	9.45	31	59.35
n=71	SD	4.17	9.32	10.43	9.2
Mackerel	mean	73.45	10.77	18.56	66.51
n=13	SD	3.3	2.69	11.26	7.99
Trout	mean	72.95	8.55	35.38	53.4
n=27	SD	5.06	2.39	8.13	6.71
RANGES		**72-80%**	**9-12%**	**19-35%**	**53-69%**

Table 2. Vitamin composition of wild-caught fish obtained near St. Catherines Island, GA and commercial fish species utilized in feeding programs at the Wildlife Conservation Society, Bronx, NY. All data presented in IU/kg on a dry matter basis.

SCI FISH

Fish	Statistic	VitA IU/kg	Vit E IU/kg
Bumper	mean	39187.0	107.3
n=2	SD	21845.0	69.0
Striped Anchovy	mean	42600.0	96.8
n=1	std.dev		
Southern Kingfish	mean	11937.0	80.4
n=2	SD	4530.0	19.1
Bay Anchovy	mean	5170.0	47.2
n=6	SD	2266.0	12.3
Striped Mullet	mean	61723.0	123.1
n=3	SD	48432.0	32.7
Inland Silverside	mean	16949.0	260.2
n=7	SD	7262.0	108.6
Pompano	mean	24206.0	128.2
n=2	SD	6393.0	17.1
Star Drum	mean	103130.0	46.1
n=1	SD		
Striped Killifish	mean	17235.0	738.2
n=1	SD		
RANGES		**5170-103130 IU/kg**	**46-738 IU/kg**

COMMERCIAL FISH

Fish	Statistic	VitA IU/kg	Vit E IU/kg
Whitebait	mean	52794.4	285.6
n=6	SD	27552.9	95.2
Capelin	mean	26154.1	116.5
n=35	SD	22734.7	97.8
Spearing	mean	23919.0	226.2
n=7	SD	13562.4	168.4
Herring	mean	20988.3	66.4
n=54	SD	21832.9	63.3
Mackerel	mean	214215.4	184.2
n=13	SD	155627.9	66.2
Trout	mean	18488.9	309.7
n=21	SD	20922.3	277.1
RANGES		**18489-214215 IU/kg**	**66-310 IU/kg**

Table 3. Macromineral composition of wild-caught fish obtained near St. Catherines Island, GA and commercial fish species utilized in feeding programs at the Wildlife Conservation Society, Bronx, NY. All data presented on a percent dry matter basis.

SCI FISH

Fish	Statistic	Ca	Mg	Na	P	K
Bumper	mean	5.73	0.31	0.89	3.53	1.18
n=2	SD	0.95	0.04	0.73	0.17	
Striped Anchovy	mean	4.54	0.30	0.38	2.29	
n=1	SD					
Southern Kingfish	mean	5.58	0.27	0.88	3.16	0.92
n=2	SD	1.42	0.01	0.61	0.40	
Bay Anchovy	mean	3.52	0.31	1.56	2.15	0.93
n=6	SD	0.35	0.08	0.69	0.46	0.31
Striped Mullet	mean	4.55	0.22	0.82	2.78	1.11
n=3	SD	0.58	0.08	0.45	0.64	0.06
Inland Silverside	mean	4.99	0.28	1.01	3.13	1.05
n=7	SD	1.15	0.04	0.21	0.81	0.08
Pompano	mean	5.00	0.26	1.26	2.83	1.27
n=2	SD	1.88	0.03	0.18	0.06	0.13
Star Drum	mean	6.38	0.26	1.08	3.33	1.06
n=1	SD					
Striped Killifish	mean	5.62	0.17	0.47	3.17	0.48
n=1	SD					
RANGES		**3.5-6.4**	**0.2-0.3**	**0.4-1.6**	**2.2-3.5**	**0.5-1.3**

COMMERCIAL FISH

Fish	Statistic	Ca	Mg	Na	P
Whitebait	mean	2.90	0.10	0.70	2.50
n=4	SD	0.30	0.10	0.04	0.30
Capelin	mean	1.50	0.10	1.40	2.00
n=14	SD	0.60	0.10	0.40	0.60
Spearing	mean	3.00	0.13	0.60	2.40
n=3	SD	0.40	0.10	0.20	0.20
Herring	mean	1.80	0.21	1.00	1.70
n=18	SD	0.90	0.10	0.40	0.60
Mackerel	mean	2.00	0.50	1.00	2.00
n=8	SD	0.90	0.70	0.30	0.50
Trout	mean	2.20	0.20	0.48	1.90
n=12	SD	0.80	0.10	0.13	0.40
RANGES		**1.8-3.0**	**0.1-0.5**	**0.5-1.4**	**1.7-2.5**

n = number of separate catches analyzed; each sample represents a pooled catch containing numerous individuals

Table 4. Trace mineral composition of wild-caught fish obtained near St. Catherines Island, GA and commercial fish species utilized in feeding programs at the Wildlife Conservation Society, Bronx, NY. All data presented in µg/g on a dry matter basis.

SCI FISH

Fish	Statistic	Cu	Fe	Mn	Zn	Co	Cr	Mo
Bumper	mean	6.61	205.20	12.20	90.62		9.60	
n=2	SD	2.41	59.12	2.26	2.10			
Striped Anchovy	mean	7.65	126.97	22.73	141.28			
n=1	SD							
Southern Kingfish	mean	6.55	557.91	35.70	75.15		76.00	3.30
n=2	SD	2.90	546.01	5.80	0.50			
Bay Anchovy	mean	4.19	269.57	14.03	138.58		14.16	1.70
n=6	SD	3.38	176.78	3.17	29.51		11.13	
Striped Mullet	mean	6.69	545.42	34.32	65.03		9.70	
n=3	SD	1.19	603.07	33.81	10.68		8.20	
Inland Silverside	mean	4.02	206.81	16.84	143.03	2.40	12.28	1.70
n=7	SD	3.06	80.79	10.91	16.05	0.57	6.90	
Pompano	mean	5.05	389.00	16.45	82.80		27.60	1.60
n=2	SD	1.20	182.43	3.47	5.66		7.64	
Star Drum	mean	4.50	604.00	25.40	59.80		59.80	2.60
n=1	SD							
Striped Killifish	mean	7.92	268.00	13.30	113.00		23.20	
n=1	SD							
RANGES		**4.0-7.9**	**127.0 -604.0**	**12.2-35.7**	**59.8-143.0**		**9.6-76.0**	**1.6-3.3**

COMMERCIAL FISH

Fish	Statistic	Cu	Fe	Mn	Zn
Whitebait	mean	2.90	191.90	9.00	71.00
n=4	SD	1.70	81.60	2.50	16.10
Capelin	mean	3.10	66.30	3.40	53.07
n=14	SD	2.00	41.42	2.11	12.32
Spearing	mean	4.70	80.60	7.80	97.40
n=3	SD	3.30	41.80	2.40	40.00
Herring	mean	7.00	112.00	10.50	68.60
n=18	SD	6.40	26.40	13.20	17.10
Mackerel	mean	6.30	151.70	4.70	56.70
n=8	SD	5.20	47.20	2.00	18.50
Trout	mean	6.70	57.90	6.30	106.90
n=12	SD	4.20	15.30	2.40	31.50
RANGES		**2.9-7.00**	**57.9-191.9**	**3.4-10.5**	**53.07-106.9**

n = number of separate catches analyzed; each sample represents a pooled catch containing numerous individuals