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The influence of environmental temperature and dietary factors on utilization of dietary energy and protein in purified diets by alligators, *Alligator mississippiensis* (Daudin)

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ABSTRACT

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Alligators reared for 8 weeks on purified diets at 32°C averaged greater feed intake and body weight gain, but poorer feed efficiency ratios, than those grown at 28°C. Environmental temperature had no effect on apparent digestibility of protein (95.4%), fat (96.1%), or energy (93.5%). Both isolated soybean protein (40% of dietary protein) and corn dextrin (16% of gross energy) were efficiently digested. High-solubility corn dextrin was slightly, but significantly, more digestible than low-solubility corn dextrin. Protein digestibility was greater when high-solubility corn dextrin was fed. Added taurine (0.1% of diet) improved body weight gain and resulted in greater fat digestibility. In a second experiment, digestibility of dietary protein and fat from purified diets were high (97.3 and 92.8%, respectively) and found to be influenced by dietary fat. Digestibility coefficients for protein, but not fat, were influenced (greater) when feces were allowed to remain in water for up to 6 h prior to collection for digestibility determinations. Digestibility of individual fatty acids varied with fat source. Stearic acid was the least digestible (77%), whereas the apparent digestibility of lauric, eicosenoic and docosapentaenoic acids was the greatest (100%). Fecal collection condition (wet vs dry) influenced the digestibility coefficients of some, but not all, fatty acids.

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INTRODUCTION

The farming of American alligators (*Alligator mississippiensis*) and other crocodilian species is an important source of quality crocodilian skins. In the United States, over 200 alligator farms have been established in the southeastern states. Moreover, alligator meat sold to seafood retailers and restaurants represents a significant source of income for alligator-farming operations.

The emergence of this aquacultural industry during the 1980's has created a demand for commercially manufactured feeds. Formulation of practical feeds for alligators has been complicated by a lack of information but recent studies on nutrient requirements (Staton and Edwards, 1987; Staton et al., 1988, 1990a,b,c,d,e) have yielded information useful in practical feed formulation. Attention has been focused on nutritional limitations which have been attributed to this species. These include a reported inability of alligators to digest or utilize plant proteins and carbohydrates other than glucose (Coulson and Hernandez, 1983) or to prosper on diets containing relatively modest amounts of fat (Coulson et al., 1987a). However, recent studies (Coulson et al., 1987b; Staton and Edwards, 1987; Staton et al., 1990c,d) do not support these earlier findings. This is of considerable practical interest as the bulk of energy sources in conventional feeds falls into these categories. In the present report, we confirm that alligators can efficiently utilize processed carbohydrate and protein of plant origin. Data presented herein also demonstrate that utilization of dietary fat, energy and protein are influenced by various dietary factors (fatty acid composition, taurine content, carbohydrate solubility). Furthermore, the influence of environmental temperature on growth performance and apparent nutrient digestibility is evaluated.

MATERIALS AND METHODS

Animals and housing

The present studies were conducted with alligators incubated and hatched at the Rockefeller Wildlife Refuge (Grand Chenier, LA) using the methods of Joanen and McNease (1977). Hatchling alligators were transported by automobile to Athens, Georgia. Prior to the initiation of experiments or between experiments, animals were fed ground beef or pork supplemented with vitamins (McNease and Joanen, 1981) or formulated diets deemed to be adequate based on experience in our laboratory.

Experiment I was conducted for a total of 8 weeks. Alligators were housed in rectangular, 0.6-m-deep, covered, fiberglass-lined tanks (see Staton et al., 1988 for a description). Each tank provided a total living area of 0.9–1.1 m^2 which was partitioned into two identical pens in which the living space was divided into dry and water (4–8 cm deep) areas in a 1:2 ratio. Tank water was supplied from a heated recirculating water system which maintained water temperature at 28 or 32°C (±1°C). Alligators were individually weighed (±0.5 g) and randomly assigned to each pen with the constraint that average weight/pen (406 to 424 g for four alligators/pen) was statistically equal and within-pen variation was minimal. Four pens were then randomly assigned to each dietary treatment group. Average body weights were determined (±0.5 g) collectively for each pen at 3 and 8 weeks into the experiment. Feed efficiency was calculated over the last 5 weeks of the experiment. Alligators were fed three times weekly, and the tanks were cleaned after each feeding. Except for periods of feeding and cleaning, alligators were housed in total darkness.

Experiment II was conducted with 27 10-month-old alligators weighing 1185

TABLE 1

Composition of experimental diets

Ingredients	Percent of diet	
	Experiment I	Experiment II
Fat[1]	12.00	10.00
Corn dextrin[2]	18.00	-
Casein	32.70	44.35
Isolated soybean protein	24.45	32.80
Gelatin	2.00	2.00
Glycine	2.00	2.00
DL-methionine	0.30	0.30
Tryptophan	0.20	0.20
Carboxymethyl cellulose[3]	2.00	2.00
Limestone	1.50	0.50
Deflourinated phosphate	1.50	2.50
Potassium carbonate	1.40	1.40
Vitamin premix[4]	0.50	0.50
Sodium chloride	0.75	0.75
Magnesium carbonate	0.35	0.35
Trace mineral premix[5]	0.20	0.20
Chromic oxide	0.10	0.10
Selenium premix[6]	0.05	0.05

[1]Poultry fat in Experiment I; in Experiment II, treatments consisted of variations in dietary fat/oil, including coconut fat, olive oil, safflower oil, linseed oil, lard, beef tallow, poultry oil, fish oil, and a mixture of 40% lard, 25% fish oil, 20% linseed oil, and 15% safflower oil.

[2]Water solubility (10% vs 80%) of dextrin (Sigma Chemical Co., St. Louis, MO) was one treatment in Experiment I.

[3]High-viscosity carboxymethyl cellulose (Sigma Chemical Co., St. Louis, MO)

[4]Provided the following per kg of diet: vitamin A as all-*trans*-retinyl acetate 18 000 IU; cholecalciferol, 2000 IU; vitamin E (all-*rac*-α-tocopheryl acetate), 150 IU; menadione sodium bisulfite, 25 mg; thiamin, 15 mg; riboflavin, 15 mg; pyridoxine, 25 mg; vitamin B_{12}, 0.042 mg; niacin, 200 mg; calcium pantothenate acid, 50 mg; folic acid, 4.0 mg; biotin, 1.0 mg; choline, 1500 mg; inositol, 50 mg; para-amino-benzoic acid, 50 mg; ascorbic acid, 450 mg; ethoxyquin, 150 mg.

[5]Provided the following in mg/kg of diet: Mn, 240; Zn, 200; Fe 120; Cu, 20: I, 4.2; Ca, 300–360.

[6]Provided 0.1 mg Se/kg of diet as sodium selenite.

TABLE 2

Experiment II: Average percentage composition of major fatty acids in the experimental diets

	Percentage of fatty acids								
	Coconut fat	Olive oil	Safflower oil	Linseed oil	Lard	Beef tallow	Poultry oil	Fish oil	Fat mix[2]
Fatty acids[1]									
8:0	4.2	-	-	-	-	-	-	-	-
10:0	5.2	-	-	-	-	-	-	-	-
12:0	47.5	-	-	-	-	-	-	-	-
14:0	19.4	-	-	-	-	2.5	-	10.4	3.2
16:0	10.2	12.1	7.0	5.9	24.1	22.5	21.5	20.3	17.1
16:1*n*-7	-	-	-	-	3.2	4.5	9.0	15.5	5.2
16:2*n*-7	-	-	-	-	-	1.1	-	2.2	-
18:0	11.9	2.9	2.6	3.2	14.1	13.1	5.2	3.7	8.8
18:1*n*-9	-	71.1	16.8	19.1	43.9	46.8	41.1	11.2	27.3
18:2*n*-6	-	11.5	72.4	18.1	11.0	6.7	20.7	4.3	20.0
18:3*n*-3	-	-	-	53.7	-	-	-	2.8	12.3
20:5*n*-3	-	-	-	-	-	-	-	13.7	3.3
22:6*n*-3	-	-	-	-	-	-	-	7.2	1.8
U:S[3]	0	4.7	7.6	10.0	1.4	1.4	2.3	1.3	2.3

[1]Carbon chain length: number of double bonds; major isomers of unsaturated fatty acids are indicated.
[2]25% fish oil, 40% lard, 15% safflower, 20% linseed oil.
[3]Ratio of unsaturated: saturated fatty acids.

to 2480 g. They were housed individually in 0.6×0.6 m plastic tanks containing 28–30°C water at a depth of 8 to 10 cm. A 10×20 cm plastic platform elevated above the water, which allowed animals to partially emerge from water, served as a feeding station. The experiment lasted 12 weeks, consisting of three 4-week periods. During each of the three periods, three alligators were fed one of nine experimental diets, which were assigned randomly at the initiation of each period. During the last 2 weeks of each 4-week period, feces were collected from each tank for apparent-digestibility determinations. Feed was offered at 10.00 h on 3 non-consecutive days per week. Any excess feed was removed at 15.00 h, at which time the tanks were cleaned. Following feeding/cleaning, tanks were not refilled with water until 08.00 of the following day. During the intervening period when alligators were under dry conditions, feces that had not been exposed to water was collected. Subsequently, feces exposed to tank water for up to 6 h was also collected. All fecal samples were immediately frozen. To facilitate the collection of intact feces, a plastic-coated gridded-wire bottom which lay approximately 2 cm above the tank bottom was installed. This served as a barrier to prevent alligator movements from compromising the integrity of the fecal pellet. Alligators were maintained on a 14L: 10D photoperiod.

Diets

Diets used in these studies (Table 1) were purified diets similar to those employed previously (Staton et al., 1990d). In Experiment I, dietary treatments consisted of (1) the absence or presence of added taurine (0.1% by dilution of the entire diet) and (2) the low- and high-solubility (10% vs 80%) corn dextrin (Sigma Chemical Co., St Louis, MO). In Experiment II, dietary treatments consisted of the fats/oils added as 10% of the diet. These included coconut fat, olive oil, safflower oil, linseed oil, lard, beef tallow, poultry oil, fish oil, or a mixture of fish oil (25%), lard (40%), safflower oil (15%) and linseed oil (20%). The fatty acid composition of the dietary fat is shown in Table 2.

Feed and fecal analysis

Chromic oxide was included at 0.1% as an indigestible dietary marker. Apparent digestibility of protein, energy, fat and individual fatty acids was determined by a standard equation (e.g., NRC, 1983, p. 40):

Apparent percent nutrient digestibility

$$= 100 - 100 \times \frac{(\%\ Cr_2O_3 \text{ in feed}) \times (\%\ \text{nutrient in feces})}{(\%\ Cr_2O_3 \text{ in feces}) \times (\%\ \text{nutrient in feed})}$$

Feces were freeze-dried prior to analysis. Feed and fecal chromic oxide was determined by the method of Brisson (1956). Dietary and fecal crude protein were determined using the Kjeldahl nitrogen method (AOAC, 1970). Gross energy was measured in an adiabatic bomb calorimeter (Parr Equipment Co., Moline, IL). Fat content of feed was measured using the total lipid method of Folch et al. (1957). Fecal fat was determined with a gas chromatographic method. Briefly, a known quantity of an internal standard, eicosatrienoic acid, was added to a 1-g sample of dry feces. The entire sample was hydrolyzed by stirring in ethanolic KOH at 60°C for 30 min, cooled, and the pH adjusted to 1.0 with HCl. The free fatty acids were extracted with petroleum ether and methylated by refluxing in 5% sulfuric acid in methanol (*v/v*) for 2.5 h. Fatty acid methyl esters were extracted and quantified via gas liquid chromatography using methods and column conditions as described by Nugura and Edwards (1970). The ratio between the known amount of internal standard and fatty acids was used to calculate fecal fatty acid or total fat content (excluding steroids). All analytical determinations were conducted in duplicate.

Statistical analysis

Data were analyzed by analysis of variance using the general linear model (GLM) procedures of SAS Institute (1985). Experiment I was analyzed as a $2 \times 2 \times 2$ factorial experiment.

RESULTS

Experiment I

The effects of increased temperature (32°C vs 28°C) were highly significant (Table 3), resulting in greater body weight gains (average of 115 g) and 7-week dry-matter consumption (average of 105 g). However, increased temperature negatively influenced feed efficiency. The presence of added dietary taurine significantly increased body weight gains (average of 38 g). However, added taurine did not influence feed consumption.

Digestibility coefficients for protein, and energy were high averaging 95.4, 96.1 and 93.5%, respectively (Table 4). Environmental temperature did not significantly influence nutrient digestibility. Dietary treatments did result in slight, statistically significant, differences in digestibilities. Fat digestibility was positively influenced by the presence of taurine. Energy and protein digestibility were positively influenced by high carbohydrate solubility. The differences were small (1% or less), apparently due to the overall high digestibility of the nutrients in the purified diet.

TABLE 3

Experiment I: Average production responses of alligators to environmental temperature and dietary treatments

Temperature (°C)	Carbohydrate solubility (%)	Added taurine (%)	Body weight gain[1] (g)	Dry matter consumption[2] (g)	Gain/feed[3] (g/g)
28	10	0	340	216	1.34
28	10	0.1	371	225	1.40
28	80	0	360	215	1.42
28	80	0.1	361	221	1.43
32	10	0	455	319	1.25
32	10	0.1	532	375	1.23
32	80	0	432	293	1.27
32	80	0.1	473	309	1.35
Average			415	272	1.34
s.e.m.			34	31	0.11
ANOVA $P>F$[4]					
Temperature			0.001	0.001	0.013
Carbohydrate solubility			NS	NS	NS
Taurine			0.15	NS	NS

[1]Over the 8-week experimental period.
[2]Over the last 7 weeks of the study.
[3]Over the last 5 weeks of the study.
[4]All interaction effects were non-significant ($P>0.05$).

TABLE 4

Experiment I: The influence of environmental temperature and dietary factors on apparent nutrient digestibility

Treatment	Digestibility coefficients (%)		
	Crude protein	Fat	Energy
Temperature			
28°C	95.4	95.9	93.5
32°C	95.4	96.2	93.5
Added dietary taurine			
None	95.3	95.7	93.4
0.1% of diet	95.5	96.6	93.5
Carbohydrate solubility			
Low (10%)	94.9	96.3	93.1
High (80%)	95.9	96.0	93.8
Average	95.4	96.1	93.5
s.e.m.	0.18	0.32	0.15
ANOVA $P>F$			
Temperature	NS	NS	NS
Taurine	NS	0.01	NS
Solubility	0.01	NS	0.01

TABLE 5

Experiment II: Apparent digestibility coefficients of dietary protein and fat

Dietary oil/fat	Digestibility coefficient[1] (%)	
	Protein	Fat
Coconut	97.3^{abc}	79.9^{e}
Olive	97.0^{bcd}	98.2^{a}
Safflower	96.5^{d}	98.1^{a}
Linseed	96.8^{cd}	96.5^{ab}
Lard	97.6^{ab}	85.9^{d}
Beef tallow	97.5^{abc}	91.3^{c}
Poultry oil	97.8^{a}	96.8^{ab}
Fish	97.3^{abc}	96.1^{ab}
Mix	97.3^{abc}	93.5^{bc}
Average	97.3	92.8
s.e.m.	0.35	2.4

[1]Weighted average for each dietary fat; means with different superscripts are significantly different ($P<0.05$) from other column means as determined by Duncan's new multiple-range test.

Experiment II

Results from Experiment II indicate that apparent digestibility of dietary protein and fat, as well as individual fatty acids was influenced by the com-

TABLE 6

Experiment II: Apparent digestibility coefficients of major fatty acids[1] derived from various dietary fats and oils

Fatty acid[2]	Digestibility[3] (%)	Dietary fat/oil[4]
8:0	100.0±0	1
10:0	96.3±1.26	1
12:0	89.5±1.96	1
14:0	92.3±1.75	1, 6, 8, 9
16:0	86.3±2.16	1, 2, 3, 4, 5, 6, 7, 8, 9
16:1	97.0±0.39	5, 6, 7, 8, 9
18:0	77.0±3.28	1, 2, 3, 4, 5, 6, 7, 8, 9
18:1	96.6±0.43	2, 3, 4, 5, 6, 7, 8, 9
18:2	97.0±0.54	2, 3, 4, 5, 6, 7, 8, 9
18:3	98.8±0.30	4, 8, 9
20:1	100.0±0	8
20:5	99.5±0.19	8, 9
22:5	100.0±0	8
22:6	99.7±0.22	8, 9

[1]Digestibility was calculated only for those fatty acids exceeding 2.5% of fatty acids in the dietary fat.
[2]Carbon chain length: number of double bonds.
[3]Mean ± s.e.m.
[4]1 = coconut, 2 = olive, 3 = safflower, 4 = linseed, 5 = lard, 6 = beef tallow, 7 = poultry oil, 8 = fish, 9 = mixture of lard (40%), fish oil (25%), linseed oil (20%) and safflower oil (15%).

position of dietary fat (Tables 5,6,7). Digestibility of coconut fat and lard averaged 79.9% and 85.9%, respectively, whereas other fats and oils were over 90% digestible. Oils were more readily digested than fats which were solid at room temperature. No apparent relationship existed between protein digestibility and melting point of the fat/oil.

Fat digestibility coefficients from feces collected in wet conditions averaged 93.3%, ranging from 80.4% for coconut fat to 98.5% for olive oil. For feces which were not exposed to tank water, fat digestibility coefficients averaged 91.3%, ranging from 75.9% for coconut fat to 97.8% for olive oil. Averaged across dietary treatments, these differences were not statistically significant ($P<0.05$). Digestibility of some, but not all, fatty acids (palmitic, oleic, and linoleic) was influenced by fecal collection condition (Table 7). The difference between protein digestibility coefficients made with feces collected from wet (mean = 97.4%) and dry conditions (mean = 96.9%) was very small (< 1% for most diets) but significantly different ($P<0.01$).

Long-chain monoenes and polyunsaturated fatty acids were highly digestible, as was octanoic acid. Digestibility of saturated fatty acids between 10 and 18 carbons generally decreased with increasing chain length. Stearic acid was least digestible, averaging 77% over a variety of fat sources. The fatty acids whose digestibility was most dramatically affected by fat source were stearic and palmitic acids. Whereas only 45.9% of the stearic acid in coconut fat was

TABLE 7

Experiments II: The influence of dietary fat source and fecal collection condition (wet or dry) on apparent digestibility coefficients of selected fatty acids

Dietary oil/fat	Digestibility of fatty acid (%)					
	14:0[1]	16:0	16:1	18:0	18:1	18:2
Coconut	80.4[b2]	58.7[d]	–	45.9[d]	–	–
Olive	–	97.0[a]	93.8[c]	94.0[a]	99.0[a]	97.0[a]
Safflower	–	94.5[ab]	–	92.3[a]	97.2[abc]	99.4[a]
Linseed	–	83.8[bc]	–	84.7[ab]	94.4[c]	97.6[a]
Lard	–	78.5[c]	95.3[bc]	58.4[cd]	95.8[bc]	97.6[a]
Beef tallow	95.4[a]	86.0[abc]	96.8[ab]	73.4[abc]	97.0[abc]	96.4[a]
Poultry oil	–	93.8[ab]	98.3[a]	90.7[a]	98.3[ab]	98.8[a]
Fish	97.3[a]	93.2[ab]	98.6[a]	84.2[ab]	94.0[c]	92.3[b]
Mix	94.4[a]	88.5[abc]	97.3[ab]	68.2[dc]	97.1[abc]	98.6[a]
ANOVA $P>F$						
Dietary fat	0.01	0.001	0.002	0.001	0.005	0.001
Feces (wet vs dry)	NS	0.071	NS	0.001	NS	0.001
Fat×feces (wet vs dry)	NS	0.024	NS	0.015	NS	0.001

[1]Carbon chain length: number of double bonds.
[2]Means with different superscripts are significantly different ($P<0.05$) from other column means as determined by Duncan's new multiple-range test.

digested, and 58.4% from lard, over 90% of this fatty acid was digested from safflower oil and poultry oil. Similar trends were evident with palmitic acid (Table 7).

DISCUSSION

For alligators fed practical-type diets containing from 0 to 36% extruded corn, energy digestibility ranged from 83.0 to 85.3% and was not significantly influenced by dietary corn or carbohydrate level (Staton et al., 1990c). In Experiment I of the present study, alligators digested 93.5% of energy in purified diets containing 18% corn dextrin and in which carbohydrate accounted for about 16% of total dietary energy. This further demonstrates that complex plant carbohydrates are apparently digestible by alligators. The present results also suggest that the degree to which carbohydrate is processed affects its apparent digestibility, as energy from the diet with low-solubility dextrin was slightly less digestible than from the diet with high-solubility dextrin. Similarly, the high, uniform level of energy digestibility of diets containing 0–36% extruded corn (Staton et al., 1990c) is likely to be attributable to the extrusion cooking of carbohydrates. This is further substantiated by findings (Staton, Edwards, Brisbin, Joanen, McNease, unpubl.) that alligators fed an extruded practical diet grew significantly more than those fed the same diet which had not been extruded. Carbohydrate digestibility by dogs is similarly affected by cooking (NRC, 1985).

When force-fed as single ingredients, various isolated proteins, including casein, edestin, gliadin, corn gluten and isolated soybean protein were digested slowly and incompletely by alligators (Coulson et al., 1987b). However, in the present experiments and elsewhere (Staton et al., 1990d), when alligators were fed ad libitum with purified diets in which isolated soybean made up 40% of dietary protein, 95–97% of dietary protein was digested. Results from Experiment II show that the apparent digestibility of dietary protein, fat and carbohydrate was affected by carbohydrate solubility. As with complex plant carbohydrates, it is likely that processing of plant proteins makes them more readily available to alligators. For example, raw plant protein would generally be associated with a substantial amount of unprocessed carbohydrate, and its utilization could be further inhibited by anti-nutritional factors in the raw plant feedstuff. Thus the efficiency of utilization of both plant proteins and carbohydrates by alligators is likely to be influenced by a wide variety of dietary factors. This may account for early reports of a total inability of alligators to utilize plant proteins and carbohydrates.

The apparent digestibility of dietary fat was generally high, which supports the view of Coulson and Hernandez (1983) that alligators are very efficient at digesting fat. Digestibility of fat, as well as individual fatty acids, was influenced by the dietary fat source. Generally, those fats with an unsaturated:saturated ratio (U:S) of less than 1.5 (coconut fat, lard and beef tallow) were more poorly digested than other fats. Fish oil, with a U:S of 1:3 was an exception, but its digestibility would have been enhanced by its high polyunsaturated fatty acid content and resulting low melting point. These trends in fatty acid digestibility, with respect to chain length and degree of unsaturation, were similar to those found in other animal species.

The finding that fecal collection condition (dry vs wet) only slightly affected estimates of energy and protein digestibility could be of practical significance in building a database on crocodilian nutrition. Determination of these values for feeds and feedstuffs would be facilitated by being able to use recently moistened feces because alligators were found to defecate when water was available in their pen. However, the use of wet feces could lead to a slight underestimate of, and add to, variability in the estimates of digestibility. We suggest that fecal samples be exposed to water no longer than 1 h before collection.

The significant effects of environmental temperature on production parameters found in the present experiments illustrate the over-riding influence of temperature in controlling body metabolism (e.g., Coulson and Hernandez, 1983; Coulson and Coulson, 1986; Coulson et al., 1990). Alligators digested protein, energy and fat from purified diets efficiently at both 28 and 32°C. However, the rate of digestion was probably faster at 32°C (e.g., Coulson and Coulson, 1986; Coulson et al, 1990). This would allow for a faster rate of gut turnover, which could account for the increased feed consumption and body weight gain observed at the higher temperature. Further research is required to determine if digestive efficiency would be affected by a greater temperature differential. Of particular interest would be to consider the effects of temperature on digestibility of nutrients in practical diets. In Experiment I, feed efficiency was significantly lower at the higher environmental temperature. This may have resulted from greater wastage of feed by alligators kept at the higher temperature.

Taurine is known to play a wide variety of physiological roles in mammals, including neurotransmission, central nervous system modulation, as a cardioprotective, osmoregulatory, or hypoglycemic agent, or as a component of bile salts (e.g., Huxtable, 1976, 1986; Huxtable and Pasantes-Morales, 1980; Huxtable et al., 1987). Feeding alligators a practical diet consisting of processed plant ingredients (consisting of soybean meal, sunflower meal, corn gluten meal, distillers' solubles and dextrin), Kercheval and Little (1980) found no beneficial effect when taurine was added to the diet at 500 mg/kg. The findings of Experiment I in this study suggest, however, that dietary taurine may be beneficial to, if not required by, alligators. The purified diets were formulated to be practically devoid of taurine. When taurine was added at 0.1% of diet, slight but significant increases in body weight gain and an improvement in fat digestibility resulted. A possible explanation is that the purified diet was deficient in sulfur-containing amino acids, from which taurine is normally synthesized. The methionine content (1.5% of dietary dry matter and 2.5% of dietary protein) would appear to be more than adequate, but cystine levels (0.2% and 0.5%, respectively) were relative low. Studies are currently in progress to further investigate this phenomenon.

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