USE OF DUCKWEED IN DIETS OF CHANNEL CATFISH[1]

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Abstract: Duckweed (Family Lemnaceae) was incorporated into 6 isocaloric diets which were fed for 10 weeks to channel catfish (*Ictalurus punctatus*) fingerlings in aquaria. Three diets contained surplus essential amino acids while utilizing duckweed at 0, 15, and 20 percent of the diet. Three other diets had the same levels of duckweed, but contained borderline levels of amino acids. No significant difference in mean weight gain per fish was found within each group of 3 diets. Feed conversion and kcal of energy required per g of weight gain were not statistically different for the fish fed the 6 diets.

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Traditionally, fish meal has been an irreplaceable ingredient and more recently, soybean meal has constituted a major percentage of catfish feeds (as much as 50 percent or more). Dependence upon 1 or 2 primary ingredients creates an undesirable situation in that feed prices may fluctuate widely based upon availability of the ingredients. Burke and Waldrop (1978) reported that feed costs may comprise as much as 58 percent of the annual ownership costs in commercial catfish operations in Mississippi. The identification of a low cost dependable supply of a high quality alternate protein source for inclusion into channel catfish (*Ictalurus punctatus*) feeds would greatly benefit the industry.

Raising fish in intensive culture situations often loads system effluents with nutrient concentrations which exceed permissible Environmental Protection Agency (EPA) standards. One plant family, Lemnaceae offers great potential as a feed ingredient as well as exhibiting great efficiency in removal of nutrients from wastewaters. Harvey and Fox (1973) found that *Lemna minor* removed large quantities of nitrogen and phosphorous and doubled in biomass every 4 days. Culley and Epps (1973) analyzed nutrient reduction by duckweeds in animal waste lagoons and concluded that the nutritional value of duckweeds compared favorably with that of many presently used animal feed ingredients. Rusoff et al. (1978) found that cattle fed on a duckweed-corn silage mixture ration showed an 80 percent increase in weight gain over a control group fed pure corn silage. Truax et. al. (1972) concluded that the nutritional value of duckweeds as feed for chicks and ducklings was superior to that of traditional feeds.

This study was conducted for preliminary evaluation of the usefulness of duckweed as an ingredient in channel catfish feeds.

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METHODS

Diet Formulation

Duckweed was obtained from a mixed culture at a research facility of the School of Forestry and Wildlife Management at Louisiana State University. The sample contained 4 species of duckweeds: *Spirodella oligorhiza*, *S. polyrhiza*, *Lemna gibba*, and *Wolffia* sp. The remaining feed ingredients were obtained from commercial sources.

The duckweed was dried after the manner of Lawson et al. (1974). The Mississippi State Chemical Laboratory determined the following analysis (expressed as percent of dry matter): crude protein (35.5), ash (20.1), crude fiber (23.3), nitrogen-free extract (21.7), and fat (1.4). Amino acid analyses, amino acid digestibility values (Table 1) and an energy value (627 Kcal/lb.) for duckweed were determined by Brunson (1980). The results of these analyses and calculations were combined and utilized in the formulation of the experimental diets.

Diets which would supply adequate amounts and proportions of essential nutrients, amino acids, and energy levels, and at the same time test the suitability of the duckweed as a feed ingredient were used. The experimental levels of duckweed in the diets were arbitrarily set at 0, 15, and 20 percent of the dry weight. Diets were formulated using a modification of the linear computer programming package described in Laughlin et al. (1979) to arrive at least cost formulation.

The 6 experimental diets were formulated on an isocaloric basis, with minimum restrictions placed on 3 essential amino acids, lysine, methionine, and methionine plus cystine (Table 2). The requirements for the other essential amino acids are usually met when

Table 1. Amino acid composition and digestibility for duckweed used in channel catfish feeding trials.

Amino Acid	Duckweed Percent	Digestibility Percent
Arginine	1.37	62.8
Histidine	0.39	43.3
Lysine	1.29	49.3
Phenylalanine	1.30	53.4
Leucine	1.79	52.2
Isoleucine	0.91	52.5
Methionine	0.57	56.2
Valine	1.06	56.5
Threonine	1.11	42.0
Aspartic Acid	2.30	56.7
Serine	1.07	52.8
Glutamic Acid	2.59	35.3
Proline	1.01	51.4
Glycine	1.38	38.1
Alanine	2.17	43.6
Tyrosine	1.00	64.4

Table 2. Restrictions and qualifiers used in formulation of 6 experimental channel catfish diets.

Restriction	Qualifier	Diets 1-3[1]	Diets 4-6
Energy (kcal/lb)	Equality	1075	1075
Fat	Maximum	6.00 %	6.00 %
Fiber	Maximum	10.00 %	10.00 %
Calcium	Equality	1.09 %	1.09 %
Phosphorous	Equality	0.78 %	0.78 %
Lysine	Minimum	1.70 %	1.45 %
Methionine	Minimum	0.53 %	0.45 %
Methionine + Cystine	Minimum	0.96 %	0.82 %
Yellow Corn	Maximum	10.00 %	10.00 %
Soy Bean Oil Meal	Minimum	10.00 %	10.00 %
Distillers Dried Solubles	Maximum	15.00 %	15.00 %
Cottonseed Meal	Maximum	10.00 %	10.00 %
Corn Gluten Feed	Maximum	12.00 %	12.00 %
Alfalfa Meal, 17 percent	Maximum	5.00 %	5.00 %
Milo	Maximum	30.00 %	30.00 %
Masonex	Equality	2.50 %	2.50 %
Whey, 12 percent	Maximum	1.25 %	1.25 %
Menhaden AO, Fish Meal	Equality	2.50 %	2.50 %
Vitamin Premix	Equality	2.50 %	2.50 %

[1]Diet 1: Control 1 - No Duckweed
Diet 2: 15 percent Duckweed
Diet 3: 20 percent Duckweed
Diet 4: Control 2 - 85 percent amino acids in Diet 1 - No Duckweed
Diet 5: 15 percent Duckweed - 85 percent amino acids in Diet 1
Diet 6: 20 percent Duckweed - 85 percent amino acids in Diet 1

lysine and methionine, normally the most limiting amino acids, are present in adequate amounts.

One control (Diet 1) contained no duckweed. Diets 2 and 3, containing 15 percent and 20 percent duckweed respectively, were formulated with the same nutritional restrictions as Diet 1 (Table 2). In the second group of 3 diets (4-6) the amino acids levels were reduced to 85 percent of those used for Diets 1-3. All other restrictions remained constant. These diets were designed to create a borderline level of amino acids, making it more probable that previously undetected deficiencies in the duckweed, if any, would manifest themselves in reduced performance of the diets. The second control (Diet 4) contained no duckweed while Diets 5 and 6 contained 15 percent and 20 percent duckweed, respectively.

Diet composition, proximate analyses, and amino acid analyses are given in Tables 3, 4, and 5, respectively.

Table 3. Percent composition of experimental channel catfish diets.

Ingredient	Diet 1[1]	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Duckweed	—	15.00	20.00	—	15.00	20.00
SBOM 49 percent	56.83	45.47	45.89	45.52	34.94	31.97
Rice Bran	33.06	15.22	4.16	27.06	20.28	15.44
Distillers Solubles	1.15	7.37	15.00	15.00	15.00	15.00
Rice Mill Feed	0.49	—	—	3.99	—	—
Cottonseed Meal 41.5 percent	—	—	—	3.14	—	—
Masonex	2.50	2.50	2.50	2.50	2.50	2.50
Dical 22-18.5	2.42	0.85	0.94	2.35	0.93	0.48
Menhaden AO	2.50	2.50	2.50	2.50	2.50	2.50
Limestone	0.62	—	—	0.60	0.18	0.48
Vitamin Premix[2]	0.25	0.25	0.25	0.25	0.25	0.25
Methionine (MHA)	0.17	—	0.20	0.08	—	—
Poultry By-Product Meal	—	10.84	8.43	—	8.43	11.45
Fat (Corn Oil)	—	—	0.67	—	—	0.79

[1]Diet 1: Control 1 - No Duckweed
Diet 2: 15 percent Duckweed
Diet 3: 20 percent Duckweed
Diet 4: Control 2 - No Duckweed
Diet 5: 15 percent Duckweed - 85 percent amino acids in Diet 1
Diet 6: 20 percent Duckweed - 85 percent amino acids in Diet 1

[2]Roche Custom Premix, manufactured by Dept. of Agriculture and Animal Health, Roche Chemical Division, Hoffman-LaRoche Inc., Nutley, New Jersey.

Table 4. Proximate analyses for 6 experimental channel catfish diets.

	Diet 1[1]	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Moisture (percent)	8.95	7.58	8.49	7.43	7.00	6.07
Ash (percent)	9.73	10.23	10.35	9.55	9.95	10.54
Crude Protein (percent)	29.69	37.81	38.13	33.75	36.41	36.41
Crude Fat (percent)	3.01	5.55	7.43	7.26	6.83	4.70
Crude Fiber (percent)	5.93	5.27	6.08	6.18	5.58	6.82
Nitrogen Free Extract (percent)	42.69	33.56	29.52	35.83	34.23	35.46

[1]Diet 1: Control 1 - No Duckweed
Diet 2: 15 percent Duckweed
Diet 3: 20 percent Duckweed
Diet 4: Control 2 - No Duckweed - 85 percent amino acids in Diet 1
Diet 5: 15 percent Duckweed - 85 percent amino acids in Diet 1
Diet 6: 20 percent Duckweed - 85 percent amino acids in Diet 1

Table 5. Calculated amino acid composition of 6 experimental diets for 10 essential amino acids for channel catfish, expressed as percent dry weight.

Amino Acid	Diet 1[1]	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Arginine	2.56	2.54	2.47	2.21	2.17	2.17
Histidine	0.91	0.83	0.82	0.84	0.77	0.73
Isoleucine	1.79	1.80	1.83	1.64	1.61	1.60
Leucine	2.71	2.79	2.78	2.47	2.50	2.51
Lysine	1.70	1.70	1.70	1.45	1.45	1.45
Methionine	0.58	0.53	0.53	0.48	0.48	0.50
Phenylalanine	1.87	1.82	1.85	1.72	1.65	1.62
Threonine	1.42	1.43	1.42	1.28	1.28	1.27
Tryptophan	0.52	0.45	0.43	0.44	0.39	0.37
Valine	1.94	1.95	1.93	1.78	1.76	1.75

[1]Diet 1: Control - No Duckweed
Diet 2: 15 percent Duckweed
Diet 3: 20 percent Duckweed
Diet 4: No Duckweed - 85 percent amino acids in Diet 1
Diet 5: 15 percent Duckweed - 85 percent amino acids in Diet 1
Diet 6: 20 percent Duckweed - 85 percent amino acids in Diet 1

Preparation of the Diets

All feed ingredients for each diet were ground in a Thomas-Wiley Model #4 Laboratory Mill equipped with a 1.0-mm mesh screen until a fine texture was achieved. The dry ingredients were then weighed and combined in proper proportion in a twin-shell dry blender and mixed for 5 minutes. The mixture was then transferred to a stainless steel mixing bowl and approximately 650 ml water per kg dry ingredients was added and mechanically stirred for 5 minutes. This mixture was then passed through a meat grinder fitted with 4.8-mm dies, producing long strands of feed which were manually chopped into pellets 6-7 mm in length, air dried in a forced air drier for 24 hours, packed in airtight plastic bags, and stored at 5°C.

Experimental Design

Ten channel catfish fingerlings (mean wt. 43.3 g) were stocked into each of 30 110-L flow-through aquaria which were supplied with heated well water (27.8°C). Five aquaria were randomly assigned to each of the 6 diets. Fish were fed 3 percent of body weight daily (dry weight of the diet) which was divided into 2 percent and 1 percent feedings in the morning and afternoon, respectively. The fish were weighed at the end of the third week, and bi-weekly thereafter to adjust feeding rates. When mortality occurred, the feeding rate for that aquarium was adjusted to compensate for the weight loss. Feeding trials lasted 10 weeks.

Data were analyzed using the Bartlett-Box procedure for testing homogeneity of variances, the variance ratio test, and 1-way analysis of variance. Analyses were performed on the mean percent weight gain, the feed conversion, and the kcal of energy per g of weight gain for each diet.

RESULTS AND DISCUSSION

Mean percent weight gain per fingerling was calculated for each aquarium (Table 6). Analysis of variance (ANOVA) of the mean weight gain of fish fed Diets 1-3 and of fish fed Diets 4-6 showed no differences ($P > 0.05$) between means within each group. The mean percent weight gain per fingerling was reduced when the fish were fed the diets containing the lower levels of the essential amino acids, but the addition of duckweed (in Diets 2, 3, 5, and 6) had no effect on the quality of the diets as compared with the control diets (1 and 4).

Mean feed conversion ranged from 2.43 (Diet 2) to 2.72 (Diet 4). Kilocalories of energy per g of weight gain averaged 5.74 (Diet 2) to 6.43 (Diet 4). ANOVA revealed no significant ($P > 0.05$) differences in these parameters between the 6 diets. Thus, the inclusion of duckweed into diets had no effect on the rate of feed conversion nor on the energy per g of weight gain.

Water quality was consistently good throughout the study with the exception of low dissolved oxygen during a pump failure. Fish in 2 aquaria suffered high mortality; thus, these tanks were deleted from analysis. With this adjustment, throughout the study the mortality of fish under analysis was 4.6 percent.

Since the controls were formulated to provide approximately the same nutrient levels as commercially used catfish feeds, it appears that inclusion of duckweed into commercial diets would not significantly reduce feed quality, and that duckweed may be a suitable source of protein for catfish feeds. Along with the duckweed's several other desirable attributes, it is a potential feedstuff which merits further study.

Table 6. Mean percent weight gain per channel catfish fingerling per diet.

Aquarium	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
1	—	—	86.42	78.63	88.32	81.65
2	85.77	145.90	104.10	69.41	74.61	88.41
3	117.25	80.33	82.61	71.25	82.86	92.03
4	99.32	80.90	119.49	84.01	79.03	70.23
5	72.96	69.81	71.60	96.03	81.01	85.40
Mean percent weight gain	93.83	94.24	92.85	79.87	81.17	83.54

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