Nutritional Value Of Water Hyacinth In Channel Catfish Feeds[1]

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Inasmuch as the availability of protein and energy in dehydrated water hyacinth meal is low and the palatability is poor for channel catfish, *Ictalurus punctatus* (Rafinesque), it was considered impractical to feed this material as a large percentage of the diet to catfish in an intensive feeding culture. A protein concentrate extracted from water hyacinth was compared for protein efficiency ratio (PER) with casein by feeding to fingerling channel catfish. To determine if dehydrated water hyacinth meal will contribute growth factors to catfish diets, low levels (5% and 10%) of this material were added to semipurified, vitamin-complete and vitamin-deficient diets and fed to fingerling channel catfish. Diets containing 10% dehydrated alfalfa meal were also fed to catfish for comparison with water hyacinth meal.

The PER (g weight gain/g protein fed) for the water hyacinth protein concentrate was 0.34 compared to 4.87 for casein.

Hyacinth meal improved fish growth and reduced mortality markedly when added to a vitamin-free diet but showed only a slight improvement when fed in a vitamin-complete diet. The average percentage weight gains were: 1.48 for vitamin-free diets containing no hyacinth meal; 19.62 for vitamin-free diets containing 5% hyacinth meal; 25.42 for vitamin-free diets containing 10% hyacinth meal; 31.71 for vitamin-complete diets containing no hyacinth meal; 32.68 for vitamin-complete diets containing 5% hyacinth meal; and 32.32 for vitamin-complete diets containing 10% hyacinth meal.

Hyacinth meal was markedly superior to alfalfa meal when fed in vitamin-free diets but in vitamin-complete diets neither of the plant meals showed a nutritional advantage. The average percentage weight changes were: a loss of 4.53 for the vitamin-free diets containing 10% alfalfa meal; 15.17 gain for vitamin-free diets containing 10% hyacinth meal; 72.11 gain for vitamin-complete diets containing 10% hyacinth meal; and 79.05 gain for vitamin-complete diets containing 10% alfalfa meal.

These data indicate that the aquatic plant meal contained essential vitamins and will probably promote growth in fish when fed at low levels in vitamin-poor diets.

INTRODUCTION

Recently, considerable attention has been given to harvesting aquatic plants for practical uses, namely, for two reasons: (1) to partially defray the cost of removing plants from waterways; and (2) aquatic plants may be an abundant and, possibly, economical source of nutrients in many parts of the world.

Extensive chemical analyses of water hyacinth and some other aquatic plants have been made at Auburn University by Boyd (1968, 1969) for various organic and inorganic materials which may serve as indexes of nutritional values for fish or livestock. His data indicate, generally, that these plants are very high in fibrous or cell wall materials, mainly cellulose; relatively high in inorganic materials, especially potassium; and relatively low and quite variable in protein. However, no biological evaluations were conducted to supplement the chemical analyses of these materials as potential feedstuffs for fish or terrestrial animals.

The present study was conducted to evaluate aquatic plants, primarily water hyacinth, as a component of catfish feeds through a series of feeding trials using fingerling channel catfish. It concerned measuring the palatability of the dried plant meal, determining the biological value of the protein, and ascertaining the possible contribution of growth factors to the diet by the dried plant product.

MATERIALS AND METHODS

Collection and processing of aquatic plants. During early June, 1969, water hyacinth (*Eichlornia crassipes*) and alligatorweed (*Alternanthera philoxeroides*) were collected from Lake Seminole in Florida and water willow (*Justicia americana*) was collected from Lake Ogletree near Auburn, Alabama. The plants were dried in a large forced-air dryer at 63 C for 48 hours and ground into a fine meal with a Wiley Mill using a 0.1mm mesh screen. Water Hyacinth was again collected from Lake Seminole in late July and from pond S-27 on the Fisheries Research Unit, Agricultural Experiment Station, Auburn University, Auburn, Alabama, in August and dried and ground like the earlier collected samples. The samples were analyzed for crude protein (Macro-Kjeldahl method), ash, ether extract, and cellulose. The meals were stored in air-tight containers at 18 C until used in feeding trials.

In September, 1969, approximately 150 kg of water hyacinth shoots were harvested from pond S-27 at Auburn for protein extraction with a Village press. The shoots were pressed for 3 to 4 hours and the expressed juice was collected. The exuded material was acidified with HCl to a pH of approximately 3.5 to precipitate the protein, then, set overnight to allow the flocculated protein to settle. The supernatant was decanted and the lower portion was centrifuged at 20,000 rpm for 20 minutes to concentrate the protein. The concentrate was freeze-dried and ground. Samples of the fresh plant, pressed pulp, and dry concentrate were analyzed and the percentages of recovery for dry matter, protein, ash, ether extract and cullulose were derived. The dry concentrate was then extracted three times with ethanol (8 ml/g) to yield a flavorless, lipid-free extract. The dried extract was chemically analyzed and used in experimental diets for channel catfish fingerlings.

Experimental facilities. Twenty-four, 1-cu-ft. plastic tanks were set up in a laboratory in the Fisheries Building

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at Auburn University. Each tank was equipped with a water supply, air supply and a hanging drain tube to remove the bottom water. The rate of water flow through the tanks was approximately 0.5 liter per minute.

Channel catfish fingerlings, 4 to 16 grams in weight were used as experimental subjects in the various feeding trials. Except for the plant materials being tested, all of the diet ingredients were in a highly purified form.

The diet ingredients were blended in a Hobart mixer at low speed for one hour, then, water was added and mixed first at low speed and then high speed until a ball of dough formed. The amount of water required varied from 100% of weight of the dry ingredients in mixtures containing no plant meal up to 150% in mixture with high plant meal. The plastic mass was frozen for several hours and grated with a household food grater. The grated particles (2mm in diameter and 6mm in length) were dried mildly in a forced-air oven at 50 C for 24 hours.

Palatability of aquatic plant meals. To determine palatability of the meals from dried water hyacinth, water willow and alligatorweed, diets were formulated using purified protein, cellulose, dextrin, fat, vitamins and minerals, and graded levels of various plant meals. All of the rations were maintained at a 20% protein level by varying the levels of casein. The composition of the ration is given in Table 1.

Each tank was stocked with 22 to 25 channel catfish fingerlings to a total weight of 100 grams of fish per tank. Each of the three diets was fed to four tanks of fish per diet. The fish were fed 3% of body weight daily with diets containing 20% of one of the plant meal for the first week, with a 30% plant meal diet for the second week, with a 40% plant meal diet for the third and fourth weeks. Palatability was evaluated qualitatively on the basis of how readily the fish accepted their ration when it was placed into the tank, and quantitatively by percentage weight gains for the 4-week period.

Biological evaluation of protein in water hyacinth. To determine the protein efficiency ratio (PER) of the protein from water hyacinth, the extracted protein concentrate had to be used in the diets because the poor palatability of the dried plant meal would not permit enough of the meal to be used to provide a sufficiently high protein level in the diet for estimating biological value. Casein was used as a control protein. Purified diets of 12% protein were formulated wherein the only protein source was either casein or water hyacinth extract. The composition of rations is given in Table 2.

Eight tanks were each stocked with 23 channel catfish fingerlings to give a total weight of 108 to 124 grams. Four of the tanks of fish received the diets containing the water hyacinth protein and four tanks of fish received the diets containing the control protein. Three per cent of body weight of feed was fed daily to the two groups of fish for 28 days. Fourteen-day adjustments in feed allowance was made in accordance with the weight of the fish. Weight gain and feed consumption were calculated at the end of the experiment and PER was calculated as grams of weight gained per grams of protein fed.

Growth factors in water hyacinth meal. To evaluate water hyacinth meal as a potential source of growth factors for practical catfish rations, semi-purified diets were formulated containing 5 and 10% of the dried meal, each fed with and without a complete vitamin premix. The rations were quantitatively equal in protein (30%), energy, and minerals. The composition of the diets is shown in Table 3. Twenty-four tanks of channel catfish fingerlings, from 11 to 17 grams in weight, were randomly assigned to the six test rations so that each treatment was replicated four

TABLE 2. COMPOSITION OF SEMIPURIFIED DIETS USED IN DETERMINING THE PROTEIN EFFICIENCY RATIO OF PROTEIN CONCENTRATE FROM WATER HYACINTH[a]/

Ingredients	Control	Experiment
Casein	15.8	0
Protein concentrate	0	32.7
Alphacel	35.2	18.3
Dextrin	28.0	28.0
Corn oil	5.0	5.0
Cod liver oil	4.0	4.0
Vitamin mix	3.0	3.0
Mineral mix	4.0	4.0
CMC	5.0	5.0

a/ Protein level: 12 per cent.

TABLE 1. COMPOSITION OF SEMIPURIFIED DIETS USED TO TEST PALATABILITY OF THREE AQUATIC PLANTS FED AT THREE LEVELS IN THE DIETS OF CHANNEL CATFISH FINGERLINGS /[a]

Ingredients	Water hyacinth			Water willow			Alligatorweed		
	20%	30%	40%	20%	30%	40%	20%	30%	40%
Plant meal	20.0	30.0	40.0	20.0	30.0	40.0	20.0	30.0	40.0
Casein	20.4	18.7	17.1	19.6	17.6	15.8	20.5	18.8	17.2
Alphacel	27.1	18.8	10.4	27.9	19.1	11.7	27.0	18.7	10.3
Dextrin	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Cod liver oil	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Vitamin mix[b]/	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Mineral mix[c]/	4.0	4.0	4.0	.40	4.0	4.0	4.0	4.0	4.0
CMC	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

a/ Protein level: 20 per cent.

b/ Vitamin mixture contains in milligrams per gram: Vitamin A Concentrate (200,000 units per gram), 4.5; vitamin D concentrate (400,000 units per gram), 0.25; alpha tocopharol, 5.0; ascorbic acid, 45.0; inositol, 5.0; choline chloride, 75.0; menadione (k) 2.25; Para-aminol benzoic acid, 5.0; niacin, 4.5; riboflavin, 1.0; pyridoxine hydrochloride, 1.0; thiamine hydrochloride, 1.0; calcium pantothenate, 3.0; biotin, 0.02; folic acid, 0.09; and vitamin B-12, 0.00135.

c/ USP XIV (1950) salt mixture contains in grams per kilograms: ferric ammonium citrate, 15.3; calcium carbonate, 68.6; calcium citrate, 308.3; calcium biphosphate, 112.8; magnesium carbonate, 35.2; magnesium sulfate, 38.3; potassium chloride, 124.7; dibastic potassium phosphate, 218.8; sodium chloride, 77.1; and in milligrams per kilogram: cupric sulfate, 78; manganese sulfate, 200; ammonium aluminum, 92; potassium iodide, 41 and sodium fluoride, 507.

times. The fish were fed for 28 days and weight gains were measured.

Inasmuch as the water hyacinth meal appeared to be a source of growth factors, it was compared with alfalfa meal which is used commercially for this purpose in catfish feeds. To make this comparison, semi-purified diets were formulated containing either 10% dried water hyacinth meal or 10% alfalfa meal, with and without a vitamin premix. The composition of the rations was similar to that described previously (Table 3). Four tanks of channel catfish fingerlings from 3.8 to 4.6 grams in weight were assigned to each ration for 42 days. Weight gains were measured and mortalities were calculated.

RESULTS AND DISCUSSION

Palatability of plant meals for channel catfish. By conditioning the fish to feed on 20% plant meal diets and increasing the level of plant meal to 40%, the fish showed a positive growth rate. Observations during feeding indicated that the fish consumed the diets containing water willow meal most readily, water hyacinth was next in preference and alligatorweed ranked last. As shown in Table 4, weight gains of the fish during the 28-day feeding period confirm this rank in feed preference. These data reflect relatively poor weight gains for diets which were nutritionally adequate, thus, indicating low consumption by the fish of diets containing substantial quantities of the dried plant meals.

Meal from dehydrated aquatic plants does not appear to be highly acceptable to catfish. When feed containing as much as 40% plant meal was first offered to catfish fingerlings, they refused it. By reducing the quantity of plant meal in the diet and conditioning the fish, they consumed the feeds in moderation. Table 4 shows the responses of the fish to the increasing levels of three aquatic plant meals fed over a 4-week period. The acceptability ratings, which were based upon how quickly and completely the fish consumed their rations, agree with the weight gain measurements in evaluating the three plant meals. The alligatorweed had an extremely strong grassy odor while the more palatable water willow had a more bland odor which was apparently more acceptable to the fish.

Protein extraction from water hyacinth. Table 5 presents the average yield and composition of the protein extract from the two collections of water hyacinth. The average protein percentage of the extract was 32.1. The

TABLE 4. PALATABILITY OF THREE AQUATIC PLANT MEALS FOR CHANNEL CATFISH FINGERLINGS

Plant meal	Acceptability[a] 20% (1st week)	(2nd week)	(3rd week)	Per cent weight gain
Alligatorweed	Poor	Poor	Poor	15.0
Water hyacinth	Fair	Good	Fair	33.3
Water willow	Good	Good	Good	45.0

a/ Ratings of acceptability: Excellent, Good, Fair, Poor.

TABLE 5. YIELD AND COMPOSITION OF PROTEIN CONCENTRATE EXTRACTED FROM WATER HYACINTH

Yield	
Percent of dry matter extracted	4.3
Per cent of protein extracted	10.5
Composition A%)	
Crude protein	32.1
Ether extract	7.7
Ash	7.3
Cellulose	7.9
Nitrogen-free extract	45.0
	100.0

45% nitrogen-free extract is probably composed of tannins, lignins, pectic substances, and various soluble and insoluble carbohydrate derivities which may or may not have nutritional value for fish.

The extracted protein concentrate represented a recovery of only 4.3% of the plant dry matter and 10.5% of the total crude protein. Boyd (1967) using a laboratory grinder and food press, found that water hyacinth was one of the lowest yielding aquatic plants for extracting a protein concentrate. He recovered only 12.1% of the nitrogen from water hyacinth as compared with 50.2% of the nitrogen from water willow.

With a plant providing a high yield of protein, one which is cheaply available for pressing, and with a continuous-flow, low-labor method of concentration and drying the concentrate, a material of this type may possibly have nutritional potential; however, presently, this appears inefficient on the basis of economics as well as material balance. The primary objective here was to concentrate the protein in water hyacinth and remove the "plant" flavor

TABLE 3. COMPOSITION OF SEMIPURIFIED DIETS USED TO TEST FOR GROWTH FACTORS IN WATER HYACINTH MEAL[a]/

Ingredients	Casein	Casein + Vitamins	Casein + 5% HM[b]/	Casein + 10% HM	Casein + 5% HM + Vitamins	Casein + 10% HM + Vitamins
Plant meal	0	0	5.2	10.3	5.2	10.3
Casein[c]/	40.2	40.2	38.9	37.5	38.9	37.5
Alphacel	23.8	19.8	21.5	19.4	17.5	15.4
Dextrin	20.0	20.0	18.6	17.2	18.6	17.2
Corn oil	7.0	7.0	6.8	6.6	6.8	6.6
Vitamin mix	0	4.0	0	0	4.0	4.0
Mineral mix	4.0	4.0	4.0	4.0	4.0	4.0
CMC	5.0	5.0	5.0	5.0	5.0	5.0

a/ Protein level: 30 per cent.
b/ Water hyacinth meal.
c/ Vitamin-free casein.

so that a determination of protein efficiency ratio could be made.

Protein efficiency ratio. The PER (grams gain per grams protein consumed) of water hyacinth protein was only 0.34 which was much lower than the 4.87 of casein (Table 6). However, the figure is slightly higher than the 0.31 of green algae *Chlorella pyrenoidosa* to chicks (Leveille et al 1962). The PER value of casein in rats was only 2.5. This is probably explained by the difference in body composition between catfish fingerlings and rats. The protein content of rats is higher than that of fish. The PER in rats was increased from 2.08 to 2.74 when algae protein was supplemented by 20% of fish meal and 20% corn. Boyd's (1968) amino acid compositions for several aquatic plants indicate that they are probably low in methionine and lysine.

Water hyacinth protein appears to be of relatively low biological value and if fed to fish, or other animals, apparently will have to be supplemented with the deficient amino acids to support reasonable performance.

Growth factors in water hyacinth meal. Since the use of water hyacinth in large quantities in catfish rations appears impractical because of the low quantity and quality of the protein and the poor palatability, therefore, it was decided that the most practical nutritional contribution might occur as growth factors when the plant meals are fed as small percentages of the diet. The data in Table 7 show that the addition of small quantities, 5 and 10%, of water hyacinth meal to vitamin-free diets significantly increased growth and reduced mortality of channel catfish fingerlings. The fish receiving 10% plant meals showed a slightly higher gain than those fed 5% plant meals. Rations with a complete vitamin premix but no plant meal gave slightly, but not statistically significantly, better growth than those supplied with plant meal and no vitamins. There was no advantage in adding the plant meal to diets containing the vitamin premix. Apparently the plant meal contributed no growth factors not supplied in the vitamin premix. These data indicate that the plant meal contained essential vitamins and will promote growth in fish when fed at low levels in vitamin-poor rations. The vitamins and other growth factors in water hyacinth contributing to the growth of fish have not been determined.

TABLE 6. PROTEIN EFFICIENCY RATIOS OF CASEIN AND PROTEIN CONCENTRATE FROM WATER HYACINTH FOR CHANNEL CATFISH FINGERLINGS

Protein	Number of fish tested	4-week gain	Protein efficiency ratio
		(g)	(g gain/g protein fed)
Casein	86	158	4.87
Protein concentrate	92	11	0.34

TABLE 7. GROWTH AND MORTALITY OF CHANNEL CATFISH FINGERLINGS RECEIVING DIETS CONTAINING WATER HYACINTH MEAL

Diet	Per cent weight gain	Per cent mortality
Basal	1.48	28
Basal + vitamins	31.71	0
Basal + 5% HM	19.62	0
Basal + 10% HM	25.42	0
Basal + 5% HM + vitamins	32.68	0
Basal + 10% HM + vitamins	32.32	0

Cook (1962) found that green algae *Chlorella* contained an excellent source of carotene (100,333 I. U. per grams), folic acid (72.9 mg per cent on dry weight basis), and considerable source of ascorbic acid, nicacin, riboflavin, panthothenic acid and thiamin.

Table 8 shows that after 42 days water hyacinth meal provided higher rates of growth than did commercial alfalfa meal when added to vitamin-free diets. Fish on the alfalfa meal diet actually lost weight during the last two weeks. Neither plant meal approached the vitamin premix in supplying the deficient nutrients to the basal diet. The addition of either plant meal to diets sufficient in vitamins did not improve the nutritional value.

All fish gained weight up to the fourth week of feeding but thereafter weight losses occurred for the fish fed the basal diet and that containing alfalfa meal alone.

The mortalities of the alfalfa and non-vitamin groups also increased significantly after four weeks of feeding (Table 9). No mortality up to the fourth week and only 3% after the fourth week were observed among fish fed the hyacinth meal ration. The data from these studies suggest that water hyacinth meal is superior to alfalfa meal in providing a source of growth factors to catfish feeds.

SUMMARY AND CONCLUSIONS

A series of feeding trials were conducted for the purpose of biologically evaluating aquatic plants, primarily water hyacinth, as feedstuffs for channel catfish. By conditioning the fish and gradually increasing the level of plant meal 40% of meal in the diet was consumed, but with with reluctance. Water willow was most palatable followed by water hyacinth, then, alligatorweed. The protein efficiency ratio of a protein concentrate from water hyacinth was 0.34 which was much lower than 4.87 for casein.

The most feasible nutritional contribution of water hyacinth appears to be when the plant meal is fed as a low percentage in vitamin-poor diets as a source of growth

TABLE 8. GROWTH OF CHANNEL CATFISH FINGERLINGS RECEIVING DIETS CONTAINING EITHER WATER HYACINTH MEAL (HM) OR ALFALFA MEAL (AM)

	Per cent weight gain	
	28 days	42 days
Basal	12.05	–1.45
Basal + vitamins	50.71	72.04
Basal + 10% HM	16.92	15.17
Basal + 10% AM	14.08	–4.53
Basal + 10% HM + vitamins	44.71	72.11
Basal + 10% AM + vitamins	54.29	79.05

TABLE 9. MORTALITY OF CHANNEL CATFISH FINGERLINGS RECEIVING DIETS CONTAINING EITHER WATER HYACINTH MEAL (HM) OR ALFALFA MEAL (AM)

Diet	Per cent mortality	
	28 days	42 days
Basal	2	22
Basal + vitamins	0	0
Basal + 10% HM	0	3
Basal + 10% AM	3	37
Basal + 10% HM + vitamins	0	0
Basal + 10% AM + vitamins	0	0

factors. The addition of small quantities, 5 to 10%, of hyacinth meal in vitamin-free diets increased growth and reduced mortality of channel catfish fingerlings. Water hyacinth meal provided significantly higher weight gains and lower mortality than did commercial alfalfa meal when fed in a vitamin-free diet. It may be feasible to substitute the alfalfa meal with water hyacinth meal in feeds for catfish, assuming that alfalfa has nutritional value in these feeds.

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