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Growth and organoleptic qualities of grass carp fed experimental diets

Hussain M. Bakir-Al-Hakkak

To the Graduate Council:

I am submitting herewith a thesis written by Hussain M. Bakir-Al-Hakkak entitled "Growth and organoleptic qualities of grass carp fed experimental diets." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

J. Larry Wilson, Major Professor

We have read this thesis and recommend its acceptance:

Thomas K. Hill, Douglas C. Peterson

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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Date August 3. 1985

GROWTH AND ORGANOLEPTIC QUALITIES OF GRASS CARP FED EXPERIMENTAL DIETS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Hussain M. Bakir-Al-Hakkak

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ABSTRACT

The growth of two different sizes of grass carp were studied in laboratory feeding experiments. Experimental diets included trout chow, bermuda grass pellets, and sudan grass; fish were fed at three feeding rates, 2.5, 5, and 10% of body weight. The fish that were fed trout chow showed excellent growth of small and large fish at 2.5, 5, and 10%. Bermuda grass produced good growth only in large fish at the 2.5% level and better growth at 5%. Small fish lost weight when fed bermuda grass at the 5 and 10% rates. This was probably due to the smaller fish being unable to consume the large pellets. The fish fed sudan grass at 2.5% body weight also lost weight during the six-week feeding trial.

Organoleptic comparisons indicated that there was a significant difference in the taste preference of grass carp fed bermuda grass and trout chow. The panelists preferred fish fed bermuda grass more than those fed trout chow. There was no significant difference in the taste preference among grass carp fed bermuda grass, trout chow, and sudan grass when compared to channel catfish.

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CHAPTER I

INTRODUCTION

Grass carp (Ctenopharyngodon idella), also known as white amur, is one of the largest members of the Cyprinidae. It has an elongated body with a relatively large head and terminally located mouth (Sneed 1971). Unlike the common carp, Cyprinus carpio, grass carp lack barbels (Stevenson 1975). The upper surface of the body is greenish-brown, while the sides and under surface are silvery (Cross 1969, Sneed 1971). They are native to those rivers of Siberia, Manchuria, and China which flow into the Pacific Ocean between latitudes 50 N and 23 N. They were introduced to the United States in 1963 from Malaysia to the fish Farming Experiment Station in Stuttgart, Arkansas (Stevenson 1965).

In almost every country where it has been introduced the grass carp is cultivated for food. An exception is the United States where it is grown primarily for weed control (Cross 1969). Since its introduction into the U.S., many aspects of the grass carp's biology have been investigated including food habits, potential as a cultivated food fish, and effectiveness as a biological control for nuisance aquatic vegetation.

Young grass carp begin feeding on zooplankton and phytoplankton shortly after emerging from the egg (Cross 1969). The animal constituent of the diet is replaced by vegetation before the fish reach

10 centimeters in length (Cross 1969). The omnivorousness of grass carp has been noted by a number of researchers. Lin (1935) found them to eat grass, leaves and aquatic plants, as well as small fish, earthworms, silkworm pupae, flesh of fresh water mussels, beef, insects, and even decayed cloth and shoes. Stevenson (1965) reported that fingerlings fed heavily on Daphnia, chopped earthworms, and chironomid larvae. Cross (1969) reported that, in his laboratory, grass carp of approximately 23 cm in length ate Daphnia, Tubifex worms, and Asellus as well as vegetation. Singh, Dey, and Reddy (1977) observed that small grass carp measuring between 98 to 220 mm consumed mosquito larvae and that fish up to a size of 185 mm were comparatively more voracious in feeding on mosquito larvae than the large fish (220 mm). They suggested that young grass carp 98 to 220 mm are capable of exercising some control over mosquito larvae. The larger grass carp of 252 mm did not feed on the larvae.

In studies involving the grass carp as a cultured food fish, the diverse findings of grass carp feeding studies have suggested the use of several types of natural and artificial feeds. Shireman, Colle, and Rottman (1977) reported that grass carp which were fed duckweed (Lemna minima) in circular tanks grew more rapidly at 0.53 fish/L than those stocked at higher densities. Shireman, Colle, and Rottman (1978) used two different sizes of grass carp (3 and 63 g) and fed them one of four experimental diets: (1) Purina catfish chow pellets, (2) 50% catfish chow and 50% rye grass pellets, (3) 100% rye grass pellets, and (4) fresh duckweed. In this study high biomass, excellent growth, and satisfactory survival rates were obtained when the fish were fed duckweed; the other diets were less satisfactory.

Shireman, Rottman, and Aldridge (1983) conducted an experiment to differentiate between grass carp and hybrid grass carp (grass carp ♀ x bighead carp ♂, Aristichthys nobilis). They were fed duckweed (Lemna sp.), hydrilla (Hydrilla verticillata), chara (Chara sp.), filamentous algae (Adogonium sp., Spirogyra sp.), and trout chow. They found grass carp grew best when fed hydrilla and trout chow and showed positive growth on all diets. Hybrid grass carp grew equal to grass carp when fed trout chow but did not grow when fed the vegetation diets.

Cranford and Beadles (1980) fed alfalfa pellets (15% crude protein (CP)), pelleted catfish feed (30% CP), alfalfa and bermuda grass hay (10% CP), and freshly harvested vegetation (coontail, Ceratophyllum demersum 11% CP, water smartweed, Polygonium punctatum, and aquatic primrose, Jussiaea repens, 6% CP) to 31.8 to 36.3 g grass carp at 5% body weight per day. They found that the fish fed the catfish pellets or hay yielded poor growth (0.6 or 0.5 g gain/fish/week) but those fed alfalfa pellets grew faster (8.9 g gain/fish/week). They suggested that grass carp were unable to utilize a feed containing large amounts of animal protein; however, there was mortality throughout their study. Venkatesh and Shetty (1978) used two aquatic weeds (Hydrilla verticillata and Ceratophyllum dermersum) and a terrestrial grass, the hybrid napier (a cross between elephant grass, Pennisetum purpureum, and sajje (Golgeri-1) P. typhoideum), as feed material for the grass carp. They found that growth attained by grass carp fed hybrid napier was nearly three times the growth gained with Hydrilla and about five times the growth gained with Ceratophyllum.

Mgbenka (1983) evaluated three pelleted supplemental feed in intensive feeding of grass carp in earthen ponds. The three feeds were commercial catfish ration and two modified foods in which dehydrated alfalfa meal comprised 19.3% and 38.5% of the catfish ration formula. The result of this study indicated that the fish grew satisfactorily on a commercial type catfish feed; the inclusion of 19.3% alfalfa meal in the formula improved growth slightly. There was no difference observed in fish fed the 38.5% ration.

Sensory evaluation uses the senses of taste, smell, touch, sight, and hearing to evaluate or measure physical properties of food (Amerine, Pangbonn, and Roessler 1965; Larmond 1973, 1977). The use of these responses has many applications in the entire research and development department in such areas as product matching, product improvement, cost reduction, quality control, and many other areas. Moreover, it plays an important role in new products development (Larmond 1977; Erhardt 1978; Tassan 1980; IFT 1981).

Grass carp have been widely scattered in many states in the United States as a biological control agent for nuisance vegetation in aquatic system (Guillory and Gasaway 1978). Pflieger (1978) reported that grass carp have been been evaluated by fishermen as a potential food fish because it is easy to clean, has a high percentage of usable flesh, and has good flavor. Avault (1971) reported on informal taste tests on grass carp along with several other species, including channel catfish, and found that grass carp ranked first. Wilson and Cottrell (1979) conducted a taste panel and reported that grass carp was preferred less than channel catfish ($p = 0.05$), but more so than bluegill or largemouth bass.

The purpose of this study was to compare growth of grass carp in circular tanks fed three diets (trout chow pellets, bermuda grass pellets, and chopped sudan grass) at three feeding rates (2.5, 5.0, and 10.0% body weight). The effects of fish size and stocking density were also evaluated. In addition, organoleptic properties of grass carp fed the three diets were compared to those of the channel catfish (*Ictalurus punctatus*).

CHAPTER II

METHODS

The fish in these experiments were obtained from the TWRA Eagle Bend Hatchery in Clinton, Tennessee. They had been used in rearing ponds for algae control and ranged from approximately 12 to 24 months in age. Four feeding experiments were conducted using two size groups of grass carp (average weight for small fish = 28.9 g, large fish = 590.5 g). Three diets (bermuda grass pellets, trout chow pellets, and chopped sudan grass) were fed to fish at three different rates (10.0, 5.0, and 2.5% of body weight). All diets were subjected to proximate analysis to determine relative amounts of crude protein, crude fiber, and ash.

The feeding experiments were conducted in two locations, the Holston fisheries barn and the remainder in the fisheries laboratory located at The University of Tennessee, Knoxville. A 12/12-hr light-dark photoperiod was used in all growth studies in the lab and the ambient diurnal-nocturnal period was used in the barn. A summary of the experimental design and diet/feeding rate data is presented in Table 1.

All fish used in the experiments were maintained in 122 cm diameter circular tanks with venturi type drains. All tanks in all the experiments were covered with netting to prevent the fish from jumping. The flow-through water supply (approximately 2.8 to 5.4

Table 1. Summary of Experimental Feeding Study.

Test/ Location	Tank	Number of Fish	Diet*	Rate (%)	Initial Mean Body Weight (g)
1. Barn	1	30	1	10	21
	2	30	1	10	21
	3	30	2	10	21
	4	30	2	10	21
2. Lab	1	20	1	10	36
	2	20	2	10	20
	3	20	1	5	468
	4	20	2	5	400
	5	20	1	10	37
	6	20	2	10	20
3. Lab	2	18	2	5	552
	3	18	1	5	30
	4	18	1	5	475
	5	17	2	5	37
4. Lab	1	15	1	2.5	500
	2	15	2	2.5	698
	3	15	3	2.5	676
	4	15	3	2.5	787
	5	15	2	2.5	556
	6	15	1	2.5	729
Barn	1	15	1	2.5	680
	2	15	2	2.5	579
	3	15	3	2.5	637
	4	15	3	2.5	671
	5	15	2	2.5	607
	6	15	1	2.5	662

*1 = Bermuda grass
2 = Trout chow
3 = Sudan grass

L/min) from a municipal source was dechlorinated with carbon filters. After two experiments water coming into the tanks was deflected off polyethylene baffles to increase aeration and decrease supersaturation. Compressed air was also injected into each tank to help aerate and maintain adequate dissolved oxygen levels.

Fish were fed twice a day, in the morning and late afternoon, during all tests with each test extending over a six-week period. At two-week intervals, growth rate was determined by weight and length measurements of all the fish in the tank. Quinaldine was used to facilitate handling during the data collection periods.

Dissolved oxygen, chlorine, pH, and ammonia concentration levels were recorded at two-week intervals for each diet in all experiments. Temperatures were recorded periodically to be sure they were in the acceptable range (25 ± 3 C). All water quality tests were monitored by using the HACH Model DR - EL/1 portable testing kit. Prior to the initiation of the experiments, fish were acclimated to laboratory conditions for approximately four weeks. Following acclimation, fish were graded by size to insure minimum variation among experimental compartments.

Experiment 1

The first experiment was conducted in the barn beginning on 12 August 1983 by using four circular tanks and two experimental diets (two tanks with bermuda grass and two tanks with trout chow pellets). The fish were fed at a rate of 10% of total body weight. In each tank 30 small grass carp were used with fish in each tank averaging

21 g. All the fish used in the experiment were selected randomly from the acclimated stock.

Experiment 2

The second experiment was conducted in the lab beginning on 6 October 1983 by using the same fish and diets used in the first experiment, but adding two more tanks containing larger fish averaging approximately 435 g. Fish were fed at a rate of 10% of total body weight for small fish and 5% of total body weight for large fish. Twenty fish per tank were used (averaging 76, 468, 400, 37, and 20 g in tanks 1, 2, 3, 4, 5, and 6, respectively). All the fish of a given size were selected randomly for distribution into tanks.

Experiment 3

The third experiment was conducted in the lab beginning on 13 February 1984 by using four circular tanks and the two experimental diets used in Experiments 1 and 2 (bermuda grass, trout chow). All fish were fed at a rate of 5% of total body weight. Two sizes of grass carp (small and large) were used. Eighteen fish per tank were used (averaging 552, 30, 475, and 37 g in tanks 2, 3, 4, and 5, respectively). All fish used in the experiment were selected randomly for distribution into the tanks.

Experiment 4

The fourth experiment was conducted in the lab and the barn beginning on 10 July 1984 by using 12 circular tanks and three experimental diets (trout chow pellets, bermuda grass pellets, and chopped sudan grass). Six of the tanks were used in the lab and the remainder in the barn. The fish were fed at a rate of 2.5% of total body weight and only large size fish were used. Fifteen fish per tank were used averaging 500, 698, 676, 774, 556, 729, 680, 579, 637, 671, 607 and 662 in tanks 1-6 in the laboratory and tanks 1-6 in the barn, respectively. All fish used in this experiment were of similar size and were selected randomly.

Organoleptic Evaluation

Upon termination of the feeding experiments, grass carp fed the three diets (bermuda grass, trout chow, sudan grass) were held for approximately four weeks in the flow-through system. No food was given during this time. White amur were subsequently skinned and filleted and held in an air-blast freezer until used (approximately six weeks). Frozen channel catfish fillets were purchased from a local supermarket to use as a comparison sample.

All samples were prepared for taste panel assessment according to the methods of Wilson, Hord, and McCarty (1973). Organoleptic properties of the grass carp and channel catfish were evaluated by a 49-member taste panel. Deep-fried portions of each fish sample were assigned a three-digit code number which had been randomly selected in order to eliminate bias. Samples were served to the panel members under red fluorescent light to hide obvious differences in samples whose organoleptic properties were being evaluated. The samples were scored on a six-point hedonic rating scale with the following range of responses: 6 = like very much; 5 = like moderately;

4 = like slightly; 3 = dislike slightly; 2 = dislike moderately; 1 = dislike very much. The scores were tabulated and means were analyzed by Duncan's multiple range test to determine any significant differences in taste preferences.

CHAPTER III

RESULTS AND DISCUSSION

Chemical analyses of the water revealed that ammonia, pH, and chlorine levels did not differ significantly among tanks in the four experiments (Table 2). Ammonia levels were well within tolerance limits determined for other fishes (Knepp and Arkin 1973; Konikoff 1975; Worsham 1975). Dissolved oxygen levels were also within acceptable ranges throughout the four trials. Shireman et al. (1977) reported similar results when assessing the effects of feed consumption rates and stocking densities of grass carp on dissolved oxygen concentration in tanks. The most probable reason for the lack of fluctuation among chemical parameters may be related to the turnover rate in the tanks (2800 - 5400 mL/min) and the complete cleaning of the tanks after each trial (i.e., two weeks). The temperature levels (23 to 27 C) were within the optimum range for grass carp growth as reported by Russian workers (Anon. 1970).

Based on the results of temperature data and the chemical analyses of the water, it was assumed that there were no significant differences among these parameters during the entire duration of the study. In addition, it was assumed that tank location (laboratory versus barn) had no effect on test results. Therefore, type of diet, rate of feeding, initial size of fish, and fish density in tanks,

Table 2. Mean Water Quality Parameters as Determined for Water Collected from Each Feeding Trial.

Test	Diet	Temperature (C)	Oxygen (mg/mL)	pH	Ammonia/nitrogen (mg/L)	Chlorine (mg/mL)
1	Bermuda grass	26	7.0	7.2	0.0	<0.5
	Trout chow	26	6.0	7.1	0.18	<0.5
2	Bermuda grass	26	7.0	7.0		<0.5
	Trout chow	26	7.0	7.0		<0.5
3	Bermuda grass	24	9.0	7.0	1.0	<0.5
	Trout chow	23	9.0	7.0	1.0	<0.5
4	Bermuda grass	27	6.0	7.0	1.0	<0.5
	Trout chow	27	6.0	6.8	1.0	<0.5
	Sudan grass	27	7.5	7.0	1.0	<0.5

were comparable among all trials. In addition, data from replicates of each test condition were pooled to make comparisons.

Proximate analysis of all diets indicated some variations in composition (Table 3). Bermuda grass was shown to have different percentages of crude protein, crude fiber, and ash from the different batches used. The trout chow diet contained the highest protein level, averaging more than three to four times that of the bermuda grass. The sudan grass contained the lowest percentage of crude protein but had the highest level of crude fiber.

In all four feeding experiments, there was a significant difference ($p = 0.05$) in weight gain in grass carp fed trout chow and bermuda grass pellets; trout chow fed fish outgrew those fed bermuda grass pellets (Figures 1, 2, 3, and 4). In the test where sudan grass was included, it was concluded that weight gain of fish fed sudan grass was significantly lower ($p = 0.05$) than the gain with trout chow or bermuda grass. In fact, the fish lost weight during the six-week period. The two diets, bermuda grass and trout chow pellets, fed to small grass carp showed a significant difference ($p = 0.05$) between them in regard to the weight gain after six weeks. Small grass carp fed bermuda grass lost weight after six weeks, but gained weight on trout chow pellets. In fact, it was observed that small grass carp could not eat the bermuda grass because of the large size of the pellets (1.3 - 2.0 cm^3). The pellets broke apart a few seconds after throwing them into the tanks; the food then settled to the bottom. It was observed that fish did not eat food from the

Table 3. Proximate Analysis (%) of Experimental Diets.

Diet	Dry Matter	Crude Protein	Crude Fiber	Ash	Ether Extract
Bermuda grass					
Test 1, 2	92	14	30	11	2
Test 3	90	20	32	9	3
Test 4	90	14	38	7	3
Trout chow					
Test 1, 2	92	42	3	11	9
Test 3	92	51	5	10	12
Test 4	89	46	6	12	11
Sudan grass					
Test 4	-	9	41	7	2

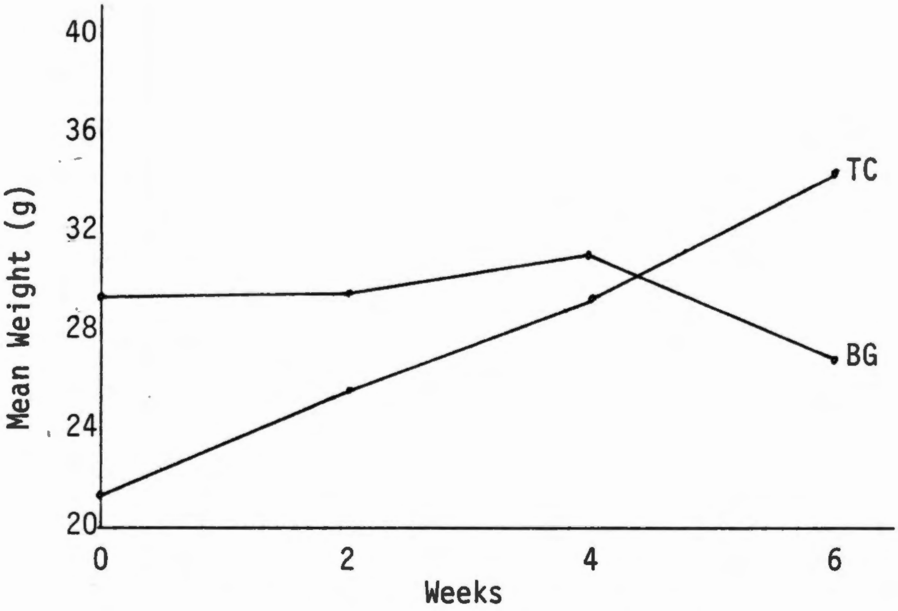

Figure 1. Mean Weight Gain for Small Grass Carp Fed Two Diets at 10% of Body Weight.

Abbreviations: BG, Bermuda Grass; TC, Trout Chow.

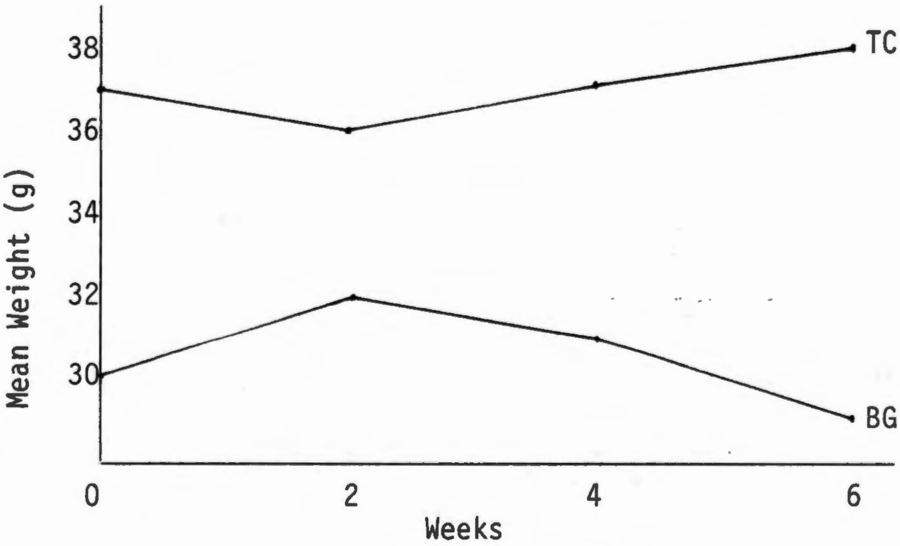

Figure 2. Mean Weight Gain for Small Grass Carp Fed Two Diets at 5% of Body Weight.

Abbreviations: BG, Bermuda Grass; TC, Trout Chow.

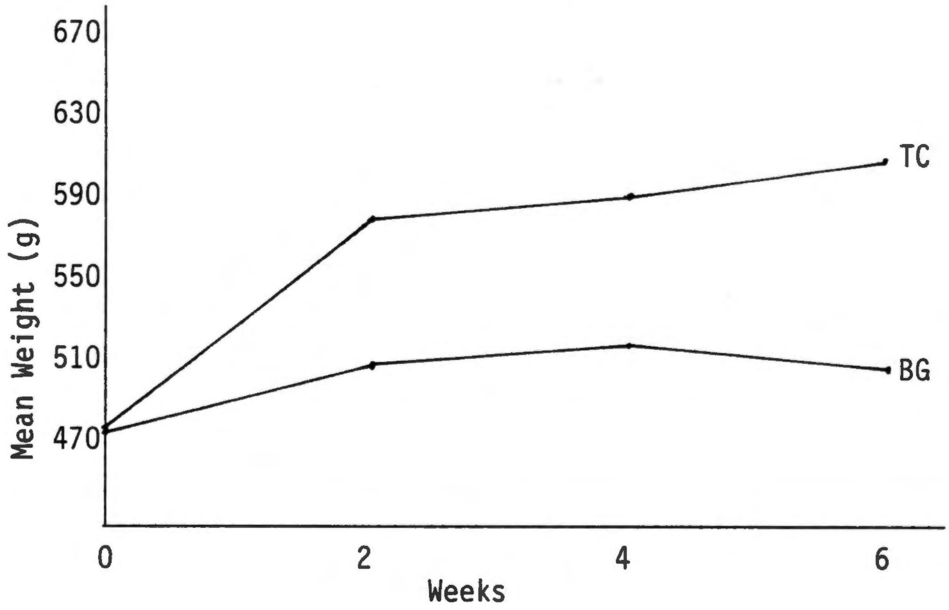

Figure 3. Mean Weight Gain for Large Grass Carp Fed Two Diets at 5% of Body Weight.

Abbreviations: BG, Bermuda Grass; TC, Trout Chow.

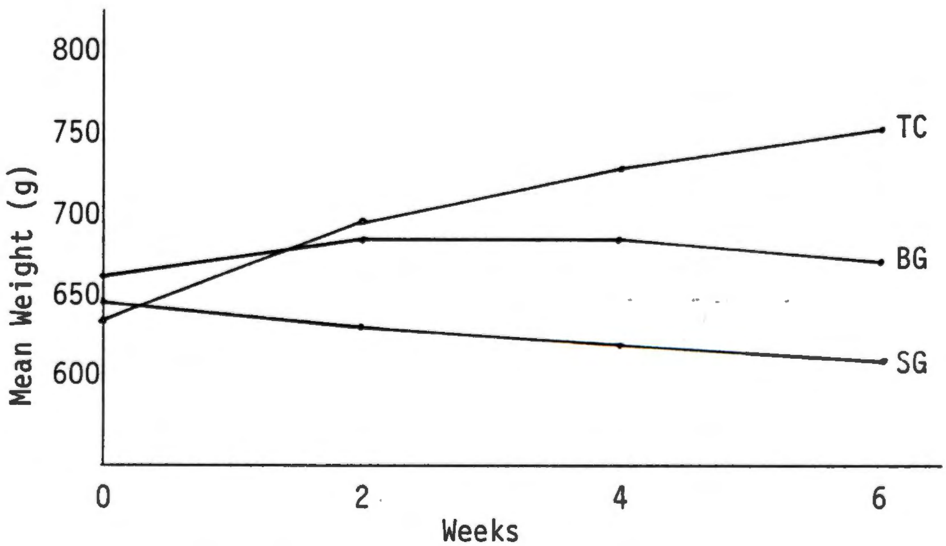

Figure 4. Mean Weight Gain for Large Grass Carp Fed Three Diets at 2.5% of Body Weight.

Abbreviations: BG, Bermuda Grass; TC, Trout Chow; SG, Sudan Grass.

tank's bottom. This observation has been confirmed by Shireman et al. (1978).

The effect of the two diets, bermuda grass and trout chow pellets, on the small fish fed at 10 and 5% rates has been analyzed statistically and, as mentioned before, significantly differ in regard to the weight gain (Figures 1 and 2). The fish fed trout chow gained excellent weight, but lost or maintained the same weight with bermuda grass diet. Identical results were demonstrated with the large fish fed at the 2.5 and 5% rates; they gained some weight at 2.5% but more weight at the 5% level.

In the fourth experiment, the three diets, bermuda grass, trout chow, and sudan grass, were fed to large grass carp at a rate of 2.5% of total body weight. There was a significant difference among the three diets ($p = 0.05$) in respect to weight gain. The large fish gained some weight with bermuda grass and excellent weight with trout chow pellets, but lost weight with sudan grass. The large fish fed bermuda grass pellets gained weight with both rates (5 and 2.5%), but those fed bermuda grass pellets at 2.5% showed a weight increase (gain) only in the first two weeks followed by weight loss until the end of the experiment.

The reason for that decline in weight was most probably related to the use of a different quality of bermuda grass pellets. The first two to three weeks the fish were fed pellets containing 20% crude protein, 32% crude fiber, and 9% ash. The last three to four weeks, the fish were fed pellets containing 14% crude protein, 38% crude fiber, and 7% ash. This difference in composition contributed to the difference in the weight gain; thus, the quality of the food plays an important role in fish growth. Therefore, the difference in the protein, fiber, and ash contents between the batches may play the main role in weight lost in the 2.5% ratio.

Tan (1970) found that, of several types of vegetation fed to grass carp in ponds, Hydrilla verticillata was an excellent food. Fish fed napier grass Pennisetum purpureum and tapioca leaves Manihot utilissimus grew more slowly than those fed hydrilla. He attributed the superiority of hydrilla to its soft nature (low fiber) and high ash (mineral) content. Shireman et al. (1978) found excellent growth when he fed duckweed to grass carp and less satisfactory results with other diets. He indicated that the duckweed and catfish culture pellets were higher in ash content than the other diets. Rye grass was low in ash and high in fiber, and for that reason, the fish produced the least weight gain. According to the literature, the high protein content does not necessarily indicate diet superiority and, as indicated by Shireman et al. (1978), that even though larger grass carp fed duckweed, catfish chow, and catfish chow ryegrass diets ingested equal amounts of total protein, they did not grow at equal rates. In the present study, the higher protein content within the same diet contributed to better growth. In addition, the combination of the protein percentages along with the ash and crude fiber percentages played an important role in one diet's advantage over another.

The initial size of fish plays a role in the percentage of weight change. As mentioned before, the small size of grass carp fed bermuda grass at 10 and 5% showed a negative weight change, but the large size showed a positive weight change at 5 and 2.5% (Table 4 and Figure 5). The small and large grass carp fed trout chow diet exhibited a positive weight change at 10, 5, and 2.5%. The large fish fed sudan grass showed a negative weight change (Figure 5).

There were no significant differences in growth due to the different densities of grass carp in experimental tanks (30, 20, 18, and 15 fish per tank). Stocking densities ranged from 0.75 to 13.1 grams of fish per liter of water. These densities were less than the ranges reported by Shireman et al. (1977) for grass carp, 38.3 to 66.5 g/L, and by Andrews, Knight, Page, Matsuda, and Brown (1971) for catfish, 20.8 to 52.9 g/L. In those studies, as in the present study, there were no differences detected due to variations in stocking densities.

No fish were lost during the period that the feeding trials were being performed. However, many fish (up to 80% in some tanks) were lost between Experiments 2 and 3. The cause of the mortalities was attributed to supersaturation of the municipal water supply and the resulting gas bubble disease in the fish. Small fish (up to 40 g) were more susceptible than larger fish. Other researchers have found similar results with younger salmonids (fry and juveniles) being less tolerant to dissolved gas supersaturation than older fish (Wood 1968; Bouck, Nebeker, and Stevens 1976). Deaerating devices were subsequently incorporated into the system prior to Experiment 3 to eliminate the problem.

In all the experiments it was observed that the fish fed the bermuda grass diet behaved differently than the fish on the trout

Table 4. Weight Change (%) of Grass Carp Fed Bermuda Grass, Trout Chow, and Sudan Grass at 10, 5, and 2.5% Rates.

Diet	Size of Fish	Weight Change (%)		
		10	5	2.5
Bermuda grass	small	-4.0	-4.0	
		-6.0		
		-13.0		
		-11.1		
		$\bar{X}$= -8.6	$\bar{X}$= -4.0	
	large		2.4	3.0
			11.8	1.4
				0.0
				-1.0
			$\bar{X}$= 7.1	$\bar{X}$= 0.9
Trout chow	small	73.1	2.5	
		61.9		
		63.8		
		49.0		
		$\bar{X}$= 61.7	$\bar{X}$= 2.5	
	large		76.5	15.0
			43.5	11.5
				17.8
				17.2
			$\bar{X}$= 60.0	$\bar{X}$= 15.4
Sudan grass	large			-3.8
				-4.2
				-4.1
				-6.1
				$\bar{X}$= -4.8

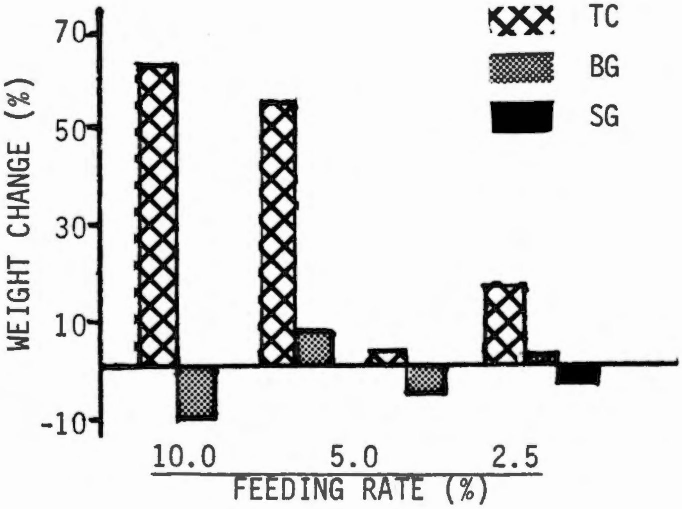

Figure 5. Weight Change (%) of Grass Carp Fed Three Diets (Trout Chow, TC; Bermuda Grass, BG; Sudan Grass, SG) at Three Different Rates (2.5, 5.0, and 10.0% Total Body Weight).

chow diet. The movement of grass carp fed bermuda grass was slower than the fish fed trout chow. At the time of feeding the fish on bermuda grass came to the surface after some food was given. On the contrary, the fish fed trout chow stayed as far away from the site of feeding as possible and did not come to the surface at all. This behavior was shown with both sizes of fish. The fish during the first week of feeding did not show this behavior but did during the second week of feeding. When the food was switched in some tanks, this behavior disappeared. This may give an indication that the fish at the beginning of the experiment were starving and the bermuda grass diet did not give them the necessary requirements to balance the depletion of the necessary body nutrients. The fish fed sudan grass diet behaved similarly to those fed trout chow. This would seem to eliminate differences in type of protein (animal versus plant) as the cause for this behavior.

Organoleptic Quality

The rating scores of the panelists and the statistical analyses are presented in Table 5. There was a significant difference in the taste preference of white amur fed bermuda grass and trout chow. The panelists preferred the fish fed bermuda grass more than trout chow. There was no significant difference in the taste preference among white amur fed bermuda grass, trout chow, and sudan grass when compared to the channel catfish. Eighty-four percent of the panelists gave scores indicating they like the taste of white amur fed bermuda grass with 82% for white amur fed sudan grass and 76% for white amur

Table 5. Rating Scores by a 49-Member Taste Panel for Grass Carp Fed Three Different Diets and Channel Catfish. Data are Numbers of Panelists Rating Each Sample. Mean Scores Followed by the Same Letter Are Not Significantly Different.

	Grass carp			
Rating*	Bermuda grass	Trout chow	Sudan grass	Channel catfish
6	14	5	6	17
5	19	17	16	9
4	8	15	18	9
3	4	9	5	8
2	2	3	3	5
1	2	0	1	1
Total	49	49	49	49
Mean	4.7a	4.1b	4.3ab	4.4ab
% Preference	84	76	82	71

*Rating scale: 6 = Like very much; 5 = Like moderately; 4 = Like slightly; 3 = Dislike slightly; 2 = Dislike moderately; 1 = Dislike very much.

fed trout chow. If all of these are compared to the catfish (which was 71% in preference), the indication is that white amur were more preferred than channel catfish.

The most worrisome problem concerning the white amur's flesh was the presence of intramuscular bones. The fish used for taste evaluation were relatively small (average weight = 750 g) and had small bones which were difficult to remove when the fish were processed. The presence of these bones in the sample may have caused some panelists to score the grass carp lower than they would have had the bones been absent. The results in this study are contrary to what Wilson and Cottrell (1979) found in that grass carp were preferred over channel catfish. This may indicate that white amur can be established as a food fish and would indeed be choice as table food.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Growth comparisons were made for two sizes of grass carp fed two experimental diets, trout chow and bermuda grass pellets, at three feeding rates (2.5, 5.0, and 10.0% total body weight). A third diet, sudan grass, was fed with the other two at the 2.5% rate. All comparisons were made in tanks with a flow-through water system. In addition, organoleptic properties of grass carp fed all three diets were compared to those of channel catfish.

Major findings from these studies were as follows:

1. In all four feeding trials, there were significant differences ($p = 0.05$) in weight gain between grass carp fed trout chow and those fed bermuda grass pellets. Trout chow fed fish grew substantially faster than those on bermuda grass.
2. Small-sized grass carp fed bermuda grass pellets lost weight after six weeks, but similar sized fish gained weight on trout chow. It was believed the small fish were unable to ingest the larger bermuda grass pellet. Large fish gained weight on both diets with the greatest increase due to trout chow.
3. The rate at which fish were fed a particular diet affected the percentage of weight change. With bermuda grass and trout chow, large fish gained more weight at 5.0% than at the 2.5% level. Although there were not enough replications for statistical

validity, small fish fed trout chow at the 10.0% level grew better than those fed at the 5.0% rate. Small fish fed bermuda grass pellets lost weight at both 5.0 and 10.0% feeding levels.

4. The initial size of the fish played a role in the percentage of weight gain. Small fish fed bermuda grass lost weight at all rates fed while large fish showed a positive change. Where comparisons were possible, large fish fed trout chow grew somewhat better than smaller fish for a given rate.
5. There were no significant differences ($p = 0.05$) in growth due to various densities of grass carp in experimental tanks (30, 20, 18, or 15 fish per tank). Stocking densities ranged from 0.75 to 13.1 g of fish per liter of water.
6. There was no mortality during the feeding trials. However, some fish were lost between trials due to supersaturation of incoming water and the subsequent gas bubble disease.
7. Grass carp fed bermuda grass behaved differently at feeding time than those fed trout chow. Trout chow fed fish remained as far from the feeding site as possible until the author moved away from the tank. Fish fed bermuda grass came immediately to the food without the avoidance behavior toward the author.
8. The organoleptic comparisons indicated that grass carp rated higher (81%) than channel catfish (71%). In addition, grass carp fed bermuda grass (84%) were preferred over those fed sudan grass (82%) or trout chow (76%).

It was concluded from this study that grass carp may be successfully reared on pelleted plant and animal feeds (bermuda grass and trout chow). It is obvious the bermuda grass diet would be the most economical if suitable growth can be attained. Additional research is needed to determine the optimum feeding rate for best growth at the least cost. In addition, indications are that grass carp may be established as choice table fare.

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VITA

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