Addition of Corn Meal to Channel Catfish, *Ictalurus punctatus*, Ponds to Improve Water Quality and Cost of Production

by

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ABSTRACT

Corn meal application was investigated as a possible method to reduce pH, unionized ammonia levels, pond flushing, and cost of fish production in advanced channel catfish, Ictalurus punctatus, ponds. Corn meal was added at an initial rate of 225 kg/ha and a follow-up rate of 112 kg/ha to each of three plastic-lined ponds stocked at 37,422 fingerlings/ha. Total ammonia-nitrogen, unionized ammonia, pH, temperature, dissolved oxygen, fish growth, yield, production, percent survival, and feed conversion between control and corn meal ponds were not significantly different ($P > 0.05$). Chlorophyll-a concentrations were significantly higher ($P \leq 0.05$) in corn meal ponds than in control ponds. Corn meal applied at the rate and frequency in this study did not appear to reduce pH, unionized ammonia concentrations, flushing requirements, or the cost of fish production.

INTRODUCTION

High total ammonia-nitrogen (TAN) levels (example LC_{50}=37.5 mg/l) are detrimental to the culture of channel catfish, Ictalurus punctatus (Knepp and Arkin 1973). The toxicity of ammonia to fish is related primarily to the levels of the unionized form (Tucker et al. 1984), of which even sublethal levels can adversely affect fish production. Prolonged exposure of channel catfish to unionized ammonia at sublethal levels (example 24-h TL_{50} = 2.36 mg/l) causes gill hyperplasia (Robinette 1976), reduced growth (Colt and Tchobanoglous 1976; Robinette 1976), and probably predisposes fish to diseases such as bacterial infections (Tucker et al. 1984).

Unionized ammonia concentration increases from TAN as pH and temperature increase (Emerson et al. 1975). Boyd et al. (1979) noted that at 30 °C and a pH of 9, approximately 45% of TAN is in the unionized form. Water quality monitoring of channel catfish culture ponds during summer months at the A. E. Wood State Fish Hatchery (AEWSFH) in San Marcos, Texas revealed elevated afternoon pH (≥9), temperatures (≥31 °C), and TAN (≥1 mg/l) concentrations in most ponds. These conditions have the potential to affect fish production; thus, remedial action is taken to reduce the effects of poor water quality. A standard practice at the AEWSFH is the plastic-lined (Hypalon®)[1] production ponds are flushed with considerable volumes of fresh water to improve water quality by dilution, a practice unnecessary in earthen ponds (McGee and Boyd 1983). Flushing contributes to the high cost of producing advanced channel catfish at the AEWSFH because water must be pumped from the San Marcos River (alkalinity = 240-250 mg/l as $CaCO_3$; hardness = 317 mg/l as $CaCO_3$; pH = 7.72-8.05; temperature = 22.8-23.4°C) into a 3.8-ha hatchery reservoir, which then supplies water to the production ponds.

Methods to control unionized ammonia concentrations in channel catfish ponds have targeted TAN and pH levels. Feeding rates are adjusted to minimize build up of TAN and nutrients that promote development of algal blooms that cause fluctuations in pH (Tomasso et al. 1979). Chemicals that increase water hardness also have been used to reduce fluctuations in pH Boyd (1990). However, these methods are not practical at the AEWSFH, which is required to produce 20.3-cm channel catfish in one season and discharge hatchery effluent of acceptable water quality. Also, attempts to control pH levels with chemicals have provided only short term solutions (Mandal and Boyd 1980; Wu and Boyd 1990). Conversely, Pote et al. (1990) reported satisfactory results in pH reduction by using corn meal in shrimp culture ponds at Mississippi State University. Similar results of pH reduction were observed at the AEWSFH when Florida largemouth bass, Micropterus salmoides floridanus, ponds were fertilized with corn meal. Corn meal has a high organic carbon content that is released as carbon dioxide through microbial respiration (Pote et al. 1990). Carbon dioxide forms carbonic acid in water which lowers water pH (Boyd 1990; Pote et al. 1990). The objective of this study was to determine if corn meal application would lower pH and subsequently unionized ammonia levels in advanced channel catfish culture ponds and reduce the dependance upon pond flushing to improve water quality.

[1] Use of trade name or manufacture's name does not constitute endorsement.

MATERIALS AND METHODS

The study was conducted in six plastic-lined ponds at the AEWSFH. Ponds were randomly assigned to treatment (corn meal ponds) and control (control ponds) groups, each group consisting of one 0.4-ha and two 0.1-ha ponds. Ponds were filled with water from the hatchery reservoir on 11 July 1994. As treatment ponds were filling, 225 kg/ha corn meal (mill ground) was evenly distributed across the water surface of each pond from the levee. Follow-up treatments (112 kg/ha) were to be applied at 7-day intervals to each corn meal pond unless any of the selected water quality threshold values was reached or exceeded. Thresholds for all ponds consisted of maintaining morning (0600-0700 hours) dissolved oxygen above 4 mg/l and afternoon pH below 10.0. At the AEWSFH, $NH_3 \leq 0.02$ mg/l (Daily and Economon 1983) has been shown to be conducive to the culture of advanced channel catfish and thus has been selected as the threshold for catfish culture ponds. Believing that this standard threshold was too low and the early flushing that may be associated with it would be counterproductive to the effects of the corn meal, the NH_3 threshold was set at 0.04 mg/l in corn meal ponds. However, the NH_3 threshold for the three control ponds had to remain at 0.02 mg/l because of the need to keep the fish alive to meet annual production and stocking goals. When threshold values were exceeded, affected ponds were flushed from the back of the pond, and follow-up treatments of corn meal were suspended until target water quality variables were within acceptable limits. Amounts of water added to ponds were estimated at 24-h intervals as described in Piper et al. (1982) and converted to liters per minute.

All ponds were stocked 1 d after filling with channel catfish fingerlings (mean total length = 66.1 mm) at 37,422 fish/ha. Fingerlings received floating commercial feed (32% protein; Rangen Inc, Buhl, ID)[1] beginning 1 d post-stocking at 4% of estimated pond biomass (assuming no losses) twice daily. At each feeding, the required feed was divided into three allotments and dispensed by hand until fish quit feeding. Remnant allotments were reweighed and final feed amounts were determined. To prevent possible retardation of growth and stress to the fish, growth estimates were made visually as fish fed at the surface. When visual determination revealed that the fish had attained a length of 200 mm, a net was used to capture at least 30 fish from each pond for an accurate length determination. Ponds were drained on 18 October 1994 when sampling indicated that the fingerlings had attained average lengths greater than 200 mm.

Water samples were collected on Mondays and Thursdays between 1400 and 1500 hours at the kettle 1 m below the water surface using a weighted bottle sampler (Boyd and Tucker 1992). Selected water quality variables were determined as follows: TAN by the Nesslerization method (APHA et al. 1992); NH_3 by using calculations described by Emerson et al. (1975); and chlorophyll-a, as an estimate of planktonic algal biomass, using the chloroform-methanol extraction method (Wood 1985). During water sample collection, water temperature, pH, and dissolved oxygen data also were collected using a YSI model 3800 Datalogger (Yellow Springs Instruments, Yellow Springs, Ohio)[1] . Morning water temperatures and dissolved oxygen concentrations were measured between 0600 and 0700 hours at the pond kettle with a YSI model 57 oxygen meter.

Repeated Measures Analysis of Variance (SAS 1988) was used to determine significant difference in water quality variables between the corn meal and the control ponds. Production data were compared by T-test. Significant level was set at $\underline{P} \leq 0.05$.

RESULTS AND DISCUSSION

Corn meal application did not influence advanced channel catfish production or water quality except for chlorophyll a levels. Mean harvest length, yield, production, feed conversion, and percent survival were similar ($\underline{P} > 0.05$) between control and corn meal ponds (Table 1). A total of 1,257 kg of feed was offered to fingerlings in corn meal ponds compared with 1,350 kg in control ponds (Table 2). This resulted in a feed conversion of 2.02 in control ponds compared with 1.59 in corn meal ponds. Apparently, channel catfish in both treatment and control ponds mainly depended on artificial feed for growth.

Corn meal was applied in two follow-up applications in all corn meal ponds until day 21 post-stocking when the NH_3 threshold was exceeded. On day 38 post-stocking, follow-up treatments resumed in all corn meal ponds, with the final application on day 76 post-stocking. Corn meal was applied six times to each treatment pond for a total in all ponds of 476.3 kg (Table 2).

Water temperature, pH, TAN, NH_3, and dissolved oxygen (Table 3) were not significantly different ($\underline{P} > 0.05$) between control and corn meal ponds. Throughout the study, ranges of water quality variables in all ponds were: temperature=19.6-32.2°C, pH=8.09-9.11, TAN=0.0272-0.8380 mg/l, NH_3=0.0051-0.1886 mg/l, and dissolved oxygen=6.55-12.97 mg/l. The high water quality values occurred for short periods of time, because they were quickly lowered by the subsequent flushing of the ponds. The mean chlorophyll-a value for corn meal ponds was significantly higher ($P \leq 0.05$) than that for control ponds and fluctuated during the study (Figure 1). Boyd (1990) reported similar fluctuations of chlorophyll-a levels in channel catfish ponds in Alabama. The high chlorophyll a (algal biomass) in corn meal ponds was attributed, at least partially, to nutrient enrichment from the corn meal applications.

Algal biomass and photosynthetic activity are important factors that influence dissolved oxygen and pH levels in fish ponds (Boyd 1990). Fluctuation of pH is also related to the buffering system of the pond water. The similarity of pH and dissolved oxygen concentration, in the presence of a significant difference in algal biomass, between control and corn meal ponds may be attributed to the high buffering capacity (alkalinity = 240 mg/l as $CaCO_3$; hardness = 317 mg/l as $CaCO_3$) of the pond water and the frequent flushing of the ponds. Pote et al. (1990) reduced pH in shrimp ponds with a higher corn meal application rate (336 - 560 kg/ha) at 3 to 4 week intervals. The low pH levels were achieved probably because of the low buffering system (90 mg/l as $CaCO_3$) and low hardness (30 mg/l as $CaCO_3$) of their pond water, the high corn meal application rate, and the static state of the ponds.

All ponds required flushing during this study. Unionized ammonia thresholds were reached in both 0.4-ha ponds 16 d post-filling and in all other ponds 20 d post-filling. All ponds experienced on-and-off cycles of fresh water additions for totals of 28.3 million and 34.1 million liters in the corn meal and control ponds, respectively (Table 2). Differences in the amounts of water used can be attributed to the higher NH_3 threshold allowed in the corn meal ponds. Since no significant differences in fish survival and growth were observed, allowing NH_3 levels greater than 0.02 mg/l in advanced channel catfish production ponds may reduce the amount of fresh water required for flushing ponds to maintain desirable water quality without impairing fish production.

Expenses (Table 2) incurred during the study were higher in the corn meal ponds. In addition to the cost of purchasing the corn meal, these ponds required more manpower associated with corn meal application and the opening and closing of water supply valves. Control ponds required a relatively more constant flushing and less frequent valve adjustment, while corn meal ponds required a more frequent valve adjustment but less flushing. The cost of water adjustments in corn meal ponds was compensated for by the reduced electrical cost associated with pumping water. Consequently, cost of production of advanced channel catfish were similar between corn meal ponds and control ponds.

Although corn meal did not reduce pH of advanced channel catfish production ponds (Figure 2), the study did provide some insight into NH_3 tolerance by channel catfish in culture ponds at the AEWSFH: advanced channel catfish can tolerate and grow reasonably well at a mean NH_3 concentration of 0.048 mg/l and pH of 8.44.

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Table 1. Mean (±SD) production variables for advanced channel catfish reared in plastic-lined ponds with or without corn meal applications at the A. E. Wood State Fish Hatchery from July 12, 1994 through October 17, 1994.

Treatment	Length (mm)	Production (kg/ha)	Yield (No./ha)	Feed (kg)	Feed Conversion[a]	Survival (%)
Corn meal	120.5 ± 64.1	1,153.6 ± 640.7	30,769.2 ± 7072.8	418.98 ± 349.21	1.59 ± 2.08	81.3 ± 16.9
Control	118.2 ± 61.0	1,309.5 ± 732.2	32,710.8 ± 3166.2	450.05 ± 402.99	2.02 ± 2.62	87.7 ± 8.1

[a] Feed conversion = weight fed (kg) / weight gain (kg).

Table 2. Cost estimates for the production of advanced channel catfish in plastic-lined ponds with or without corn meal applications at the A. E. Wood State Fish Hatchery from July 12, 1994 through October 17, 1994.

Variable		Corn meal ponds	Control ponds
Corn meal	amount (kg)	476.3	none
	corn meal cost (US$)	102.90	none
	applications in all ponds	1 initial, 5 follow-up	none
	manpower (hours)	2.63	none
	manpower cost (US$)	43.74	none
Flushing	frequency (days)	36-44	43-55
	liters (million)	28.3	34.1
	manpower[a] (hours)	6.26	4.88
	manpower cost (US$)	104.10	57.14
Electricity	cost[b] (US$)	196.54	236.74
Feed	cost (US$)	526.56	565.52
	amount (kg)	1,257	1,350
Total	manpower (hours)	8.89	4.88
	cost of study (US$)	973.84	859.40
	price per 100 fish (US$)	3.16	2.63

[a] Time for opening or closing pond valves.

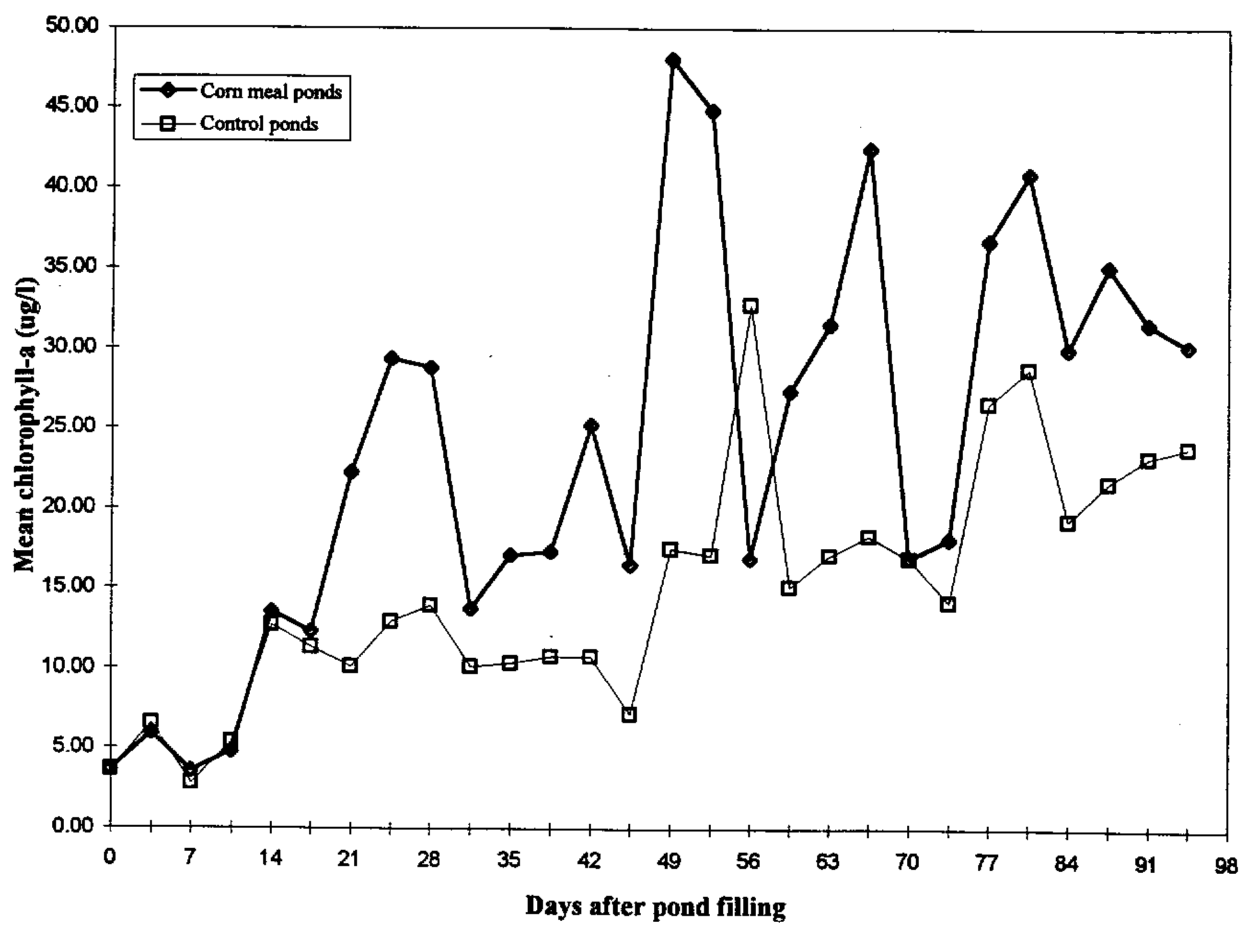
[b] Derived from a five-month average of electric pumping cost and monthly amounts of water diverted from San Marcos River for flushing study ponds.

Table 3. Mean (±SD) water quality characteristics for advanced channel catfish reared in plastic-lined ponds with or without corn meal applications at the A. E. Wood State Fish Hatchery from July 12, 1994 through October 17, 1994.

Treatment	Temperature (°C)	pH	Total Ammonia-N (mg/l)	Unionized Ammonia-N (mg/l)	Chlorophyll-a (μg/l)	Dissolved Oxygen (mg/l)
Corn meal	28.0 ± 3.0	8.44 ± 0.22	0.300 ± 0.154	0.048 ± 0.028	23.68 ± 15.11*	9.25 ± 1.13
Control	27.9 ± 3.6	8.35 ± 0.70	0.242 ± 0.135	0.036 ± 0.022	15.09 ± 10.34*	9.22 ± 1.32

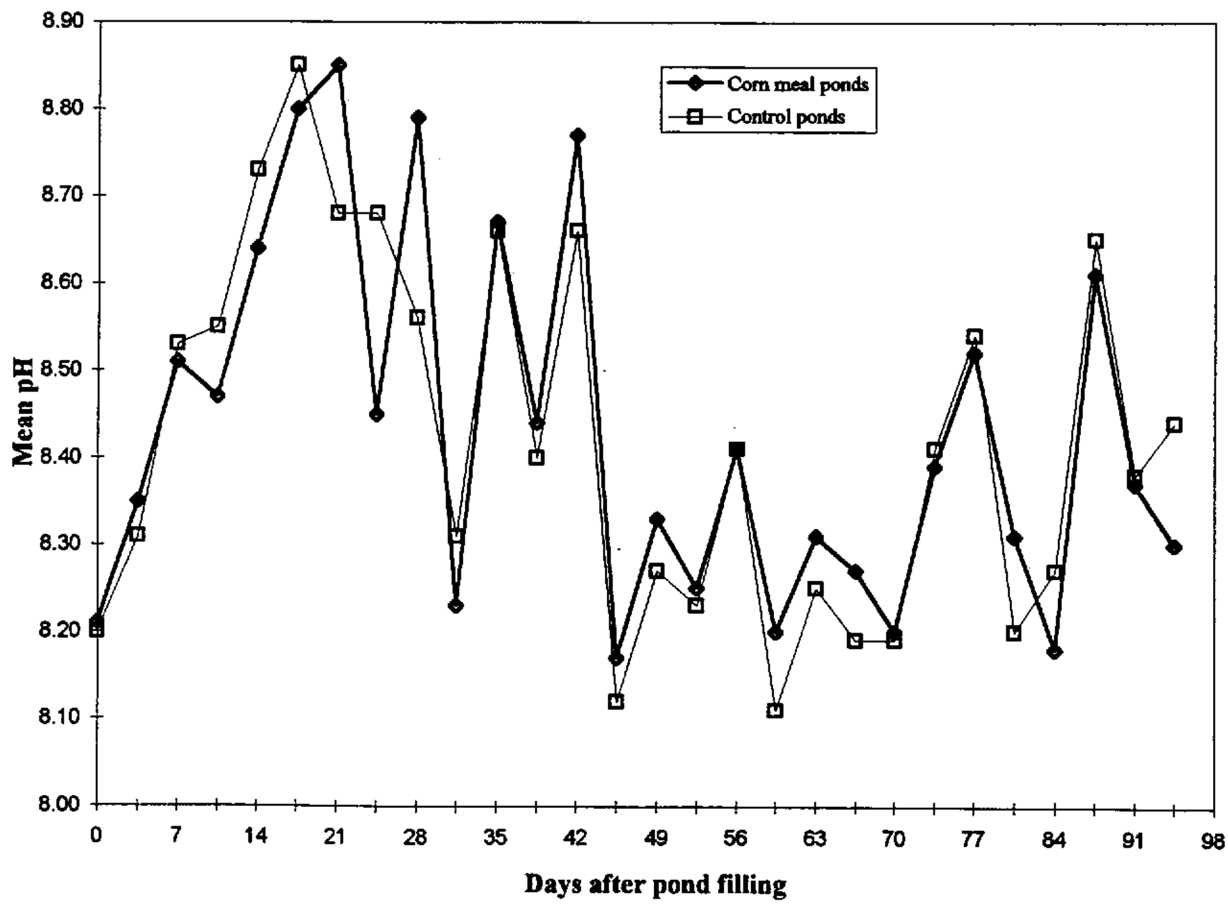
* Significantly different ($P \leq 0.05$).

Figure 1. Mean chlorophyll-a levels for advanced channel catfish reared in plastic-lined ponds with or without corn meal applications at the A. E. Wood State Fish Hatchery from July 12, 1994 through October 17, 1994.



Corn meal ponds
Control ponds
Mean chlorophyll-a (ug/l)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
0
7
14
21
28
35
42
49
56
63
70
77
84
91
98
Days after pond filling

Figure 2. Mean pH for advanced channel catfish reared in plastic-lined ponds with or without corn meal applications at the A. E. Wood State Fish Hatchery from July 12, 1994 through October 17, 1994.


Mean pH
8.00
8.10
8.20
8.30
8.40
8.50
8.60
8.70
8.80
8.90
Corn meal ponds
Control ponds
0
7
14
21
28
35
42
49
56
63
70
77
84
91
98
Days after pond filling