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Summary of Studies on Alternative Feedstuffs in Catfish Feeds

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Introduction

Soybean meal and corn have been the two most commonly used, traditional ingredients in catfish feeds. However, the cost of these feedstuffs has risen dramatically in the past few years, prompting efforts to exploit less expensive, alternative feed ingredients to reduce feed cost in catfish production. Many potential feedstuffs exist that may be nutritionally suitable for use in catfish feeds, but relatively few are readily available throughout the catfish production season. The most abundant alternative feedstuffs that can be used to replace soybean meal include cottonseed meal and corn milling by-products (i.e., corn gluten feed, corn germ meal, and distillers dried grains with solubles [DDGS]). Corn by-products also serve as a partial replacement of corn because of their low protein concentrations compared with soybean meal.

Relatively high levels of these ingredients can be used to replace soybean meal and, in some cases, corn when used individually. For example, up to 30–40% cottonseed meal can be used in catfish feeds without negatively affecting fish performance (Robinson 1991; Li and Robinson 2006; Robinson and Li 2008). Up to 50% corn gluten feed and 35% corn germ meal (highest levels evaluated) can also be used (Robinson et al. 2001; Li et al. 2013). These feedstuffs are deficient in lysine, an essential amino acid for catfish feeds, which can be compensated by synthetic lysine supplementation to meet the requirement. There may be additional savings on feed cost if a combination of two or more alternative feedstuffs is used. Studies on the use of DDGS in catfish feeds have been summarized in MAFES Research Report Vol. 24, No. 11 (Robinson and Li 2012). The present research report focuses on the use of corn gluten feed or corn germ meal along with cottonseed meal as replacements for soybean meal and corn in pond-raised catfish. Data on energy and nutrient digestibility/availability for corn by-products compared with those for soybean meal were also presented.

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METHODS

Experiment 1

Four experimental feeds (28% or 32% protein, traditional or alternative) (Table 1) were formulated to meet or exceed all known dietary requirements for channel catfish (NRC 2011) and manufactured as floating pellets at ARKAT, Inc. (now known as Dad's Dog Food) in Dumas, Arkansas. Traditional feeds contained 5% pork meat and bone/blood meal, while the alternative feeds had 20% corn gluten feed. Channel catfish fingerlings (78 pounds per 1,000) and carryover fish (0.87 pound per fish) were stocked in 0.1-acre ponds at stocking densities of 6,000 fingerlings and 2,000 pounds of carryover fish per acre in a multiple batch system at the National Warmwater Aquaculture Center in Stoneville, Mississippi. Five ponds were allotted to each dietary treatment in a complete randomized design. Fish were fed the experimental diets once daily to apparent satiation for 164 days during the growing season.

Water temperature and dissolved oxygen were measured in early morning, midafternoon, and throughout the night during the study. Nightly aeration was provided to ensure adequate dissolved oxygen in the pond water. Total ammonia-nitrogen, nitrite-nitrogen, and pH were measured every 2 weeks. Water quality was maintained in ranges considered adequate for optimum fish performance (Tucker and Robinson 1990). Chloride concentration was maintained at 100 ppm or more by the use of salt (NaCl) to alleviate possible nitrite toxicity. Dead fish were removed from ponds, weighed, and recorded for correction of feed conversion ratio (FCR) at the end of the study.

At harvest, 30 market-sized fish from each pond were selected to determine processed yield (skin-on carcass and fillet) and proximate nutrient composition. After sampling, all fish from each pond were harvested, counted, and weighed. Data collected included total feed fed, net yield, weight gain, feed conversion ratio, survival, processing yield, and fillet proximate composition. Protein, fat, and moisture were analyzed according to standard methods (AOAC 2000). All data were subjected to analysis of variance and the Fisher's protected least-significant-difference procedure (Steel et al. 1997) using Statistical Analysis System version 8.0 software (SAS Institute, Inc., Cary, North Carolina).

Experiment 2

Five 28% protein feeds in which cottonseed meal and corn gluten feed replaced 0%, 25%, 50%, 75%, or 100% of the soybean meal in the control diet were formulated to meet or exceed all known nutrient and energy requirements of channel catfish (Table 2). Levels of corn were also reduced as soybean meal replacement levels increased. The diets were manufactured at the Delta Western Research Center in Indianola, Mississippi. Stocker-sized channel catfish (0.39 pound per fish) were stocked in 0.1-acre ponds at 6,000 fish per acre. Each diet had four randomly assigned ponds. Fish were fed once daily to apparent satiation for 187 days. Other experimental conditions and data collection and analysis were the same as described for Experiment 1.

Experiment 3

This experiment examined five 28% protein diets containing decreasing levels of soybean meal (40%, 30%, 25%, 20%, and 15%) as replaced by a combination of cottonseed meal and corn germ meal (Table 3). The diets were manufactured at the Delta Western Research Center in Indianola,

Table 1. Ingredient composition of experimental diets (percentage, as-fed) used in Experiment 1.

Ingredient	28% protein		32% protein	
	Traditional	Alternative	Traditional	Alternative
Meat/bone/blood meal, pork	5.00	—	5.00	—
Soybean meal	32.60	34.20	44.40	46.45
Cottonseed meal	10.00	10.00	10.00	10.00
Corn gluten feed	—	20.00	—	20.00
Corn	29.54	20.00	27.78	20.10
Wheat middlings	20.00	12.37	10.00	—
Lysine-HCl	0.09	0.21	—	0.13
Dicalcium phosphate	0.55	1.00	0.60	1.10
C-free vitamin premix[1]	0.10	0.10	0.10	0.10
Vitamin C (Stay-C 35)[2]	0.02	0.02	0.02	0.02
Trace mineral premix[1]	0.10	0.10	0.10	0.10
Poultry fat[3]	2.00	2.00	2.00	2.00

[1]Met or exceeded requirements of channel catfish.
[2]Provide active vitamin C level ≥ 50 ppm in finished diets.
[3]Sprayed on finished diets.

Table 2. Ingredient composition of experimental diets (percentage, as-fed) used in Experiment 2.

Ingredient	Soybean meal replacement (%)				
	0	25	50	75	100
Soybean meal	51.40	38.55	25.70	12.85	—
Cottonseed meal	—	9.80	19.65	29.50	42.00
Corn gluten feed	—	10.00	20.00	30.00	34.71
Corn grain	40.66	33.73	26.60	19.47	15.00
Wheat middlings	5.00	5.00	5.00	5.00	5.00
Lysine-HCl	—	0.11	0.37	0.62	0.87
Dicalcium phosphate	1.29	1.16	1.03	0.91	0.77
Vitamin mix[1]	0.05	0.05	0.05	0.05	0.05
Trace mineral mix[1]	0.10	0.10	0.10	0.10	0.10
Catfish offal oil[2]	1.50	1.50	1.50	1.50	1.50

[1]Met or exceeded requirements of channel catfish.
[2]Sprayed on the finished pellets.

Mississippi. Each diet had five replicated ponds. Fingerling hybrid catfish (♀ channel catfish × ♂ blue catfish) (55 pounds per 1,000) were stocked in 0.1-acre ponds at 6,000 fish per acre and fed once daily to satiation for 184 days. Other experimental conditions and data collection and analysis were the same as described for Experiment 1.

Experiment 4

This experiment determined energy and nutrient digestibility/availability for corn by-products corn gluten feed, corn germ meal, and DDGS as compared with those for soybean meal. A 32% protein diet containing mostly chemically defined ingredients was used as a reference diet. Test diets were formulated to contain 70% of the reference diet mix and 30% of the test ingredient. The digestibility trial was conducted with channel catfish (0.32 pound per fish) with the indirect method (chromium oxide as the marker) using flow-through tanks at about 86°F. Fecal samples were collected by sedimentation using cylindro-conical tanks, except those for phosphorus availability, which were collected by the dissection method.

Table 3. Ingredient composition of experimental diets (percentage, as-fed) used in Experiment 3.

Ingredient	Soybean meal levels (%)				
	40	30	25	20	15
Soybean meal	40.00	30.00	25.00	20.00	15.00
Cottonseed meal	9.05	17.45	21.35	25.25	29.20
Corn germ meal	—	20.00	25.00	30.00	35.00
Corn grain	27.54	28.80	24.86	20.94	16.96
Wheat middlings	20.00	—	—	—	—
Lysine-HCl	—	0.19	0.28	0.37	0.46
Dicalcium phosphate	1.16	1.31	1.26	1.19	1.13
Vitamin mix[1]	0.05	0.05	0.05	0.05	0.05
Trace mineral mix[1]	0.20	0.20	0.20	0.20	0.20
Catfish offal oil[2]	2.00	2.00	2.00	2.00	2.00

[1]Met or exceeded requirements of channel catfish.
[2]Sprayed on the finished pellets.

Results and Discussion

Experiment 1

Two sizes of fish were stocked, but we were unable to completely separate the two groups of fish at harvest. Each pond was seined twice using a 2-inch-mesh seine, and the remaining fish in the pond were sorted by hand. There were some smaller fish mixed in the large carryover fish group, making it impossible to separate the two groups of fish accurately. Mean final weight for each treatment was reported as overall average of the two sizes (Table 4). Neither dietary protein level nor feed type (traditional or alternative) significantly affected total feed fed, net yield, final fish weight, FCR, survival, carcass and fillet yield, or fillet proximate composition. Data from this study demonstrated corn gluten feed can be used at 20% of the diet without affecting fish performance, and porcine meat and bone/blood meal, an animal protein feedstuff, added at 5% of the diet, did not improve fish growth for pond-raised channel catfish during food fish production. Similar results were obtained by researchers at Auburn University (Hu et al. 2012) and the University of Arkansas at Pine Bluff (Lochmann et al. 2012) when hybrid catfish and channel catfish were fed the same diets as in this experiment. FCR tended to be slightly lower in fish fed traditional diets containing 5% porcine meat and bone/blood meal ($P = 0.07$), but this was not observed by Hu et al. (2012) and Lochmann et al. (2012).

Experiment 2

Total feed fed, net yield, weight gain, survival, carcass yield, and fillet yield did not differ among fish fed various diets (Table 5). Fish fed diets in which 75% and 100% of the soybean meal was replaced by cottonseed meal and corn gluten feed had a significantly higher FCR than fish fed the control diet and the diet in which 25% soybean meal was replaced. Feed conversion ratio increased and net yield, carcass yield, fillet yield, fillet protein, and fat levels decreased linearly as soybean meal replacement levels increased. Diets containing high levels of cottonseed meal and corn gluten feed had higher fiber and lower digestible energy. Although the presence of some fiber in the diet may be beneficial to optimum growth of catfish (fiber serves as a source of bulk that facilitates the passage of feed through the digestive tract), high dietary fiber generally results in high FCR (Li et al. 2012). This is mainly because channel catfish cannot utilize dietary fiber, and diets containing high levels of fiber have lower levels of digestible carbohydrates and less digestible energy that are available for growth and metabolism. The fact that fish fed diets containing high levels of alternative feedstuffs had lower fat levels supports this contention. The lower carcass and fillet yield and fillet protein levels in fish fed high levels of alternative feedstuffs were likely caused by lower digestible protein or imbalance in essential amino acids even though all diets were formulated to meet or exceed requirement levels for all individual essential amino acids. Results from this experiment generally show that up to 50% soybean meal can be replaced with cottonseed meal and corn gluten feed (approximately 20% each in the diet) without marked impact on production characteristics of pond-raised channel catfish.

Experiment 3

Reducing soybean meal levels from 40% to 15% in the diet by the use of a combination of cottonseed meal and corn germ meal did not significantly affect total feed fed, weight gain, and survival of hybrid catfish (Table 6). However, FCR was significantly higher in fish fed diets containing 30% or less soybean meal than those fed the control diet (40% soybean meal). FCR increased linearly as

Table 4. Mean production and processing characteristics and fillet proximate composition of pond-raised channel catfish fed experimental diets for 164 days in Experiment 1.

	32% protein		28% protein		Pooled SE	*P*		
	Traditional	Alternative	Traditional	Alternative		Protein	Feed type	Interaction
Total feed fed (lb/acre)	17,766	18,030	17,098	17,728	553	*0.41*	*0.44*	*0.75*
Net yield (lb/acre)	9,769	9,246	9,494	9,156	300	*0.56*	*0.18*	*0.77*
Final weight[1] (lb/fish)	1.58	1.52	1.54	1.51	0.04	*0.43*	*0.20*	*0.75*
Feed conversion ratio	1.83	1.95	1.80	1.94	0.06	*0.45*	*0.07*	*0.93*
Survival (%)	92.5	92.4	93.2	92.7	1.5	*0.77*	*0.84*	*0.89*
Carcass yield[2] (%)	66.6	66.3	66.4	65.7	0.3	*0.29*	*0.18*	*0.63*
Fillet yield (%)	36.8	36.6	36.8	36.0	0.4	*0.43*	*0.26*	*0.48*
Fillet protein[3] (%)	17.9	18.1	17.7	18.0	0.3	*0.54*	*0.37*	*0.99*
Fillet fat[3] (%)	6.7	7.0	7.2	7.1	0.4	*0.42*	*0.79*	*0.57*

[1]Mean initial weight was 0.87 pound per fish for carryover fish and 78 pounds per 1,000 for fingerlings.
[2]Skin-on carcass yield.
[3]Wet-tissue basis.

Table 5. Mean production and processing characteristics and fillet proximate composition of pond-raised channel catfish fed experimental diets for 187 days in Experiment 2.[1]

	Soybean meal replacement (%)					Pooled SE	P
	0	25	50	75	100		
Total feed fed (lb/acre)	13,794	12,985	13,338	12,287	12,784	629	0.64
Net yield (lb/acre)	6,771	6,654	6,474	5,284	5,229	496	0.17
Weight gain[2] (lb/fish)	1.25	1.25	1.21	1.08	1.04	0.11	0.52
Feed conversion ratio	1.95 c	1.90 c	2.04 bc	2.19 ab	2.27 a	0.08	0.03
Survival (%)	91.4	91.6	93.1	87.3	92.7	4.1	0.88
Carcass yield[3] (%)	64.9	64.9	64.4	63.6	63.5	0.4	0.07
Fillet yield (%)	35.7	35.9	35.4	34.8	34.7	0.4	0.24
Fillet protein[4] (%)	17.9 ab	18.1 b	17.9 ab	17.6 bc	17.4 c	0.02	0.04
Fillet fat[4] (%)	5.9 ab	6.7 a	6.5 a	5.4 b	5.3 b	0.4	0.04

[1]Means within each row followed by different letter differ ($P \leq 0.05$).
[2]Initial weight was 0.39 pound per fish.
[3]Skin-on carcass yield.
[4]Wet-tissue basis.

soybean meal levels decreased. Hybrid catfish fed diets containing 20% and 15% soybean meal had significantly lower carcass yield than fish fed the control diet. Fish fed the diet containing 15% soybean meal also had significantly lower fillet yield. Both carcass and fillet yields decreased linearly with decreasing soybean meal levels in the diet. No significant differences were observed for fillet protein and fat levels among fish fed the diets containing various levels of soybean meal. Results from this experiment generally support the finding from Experiment 2. A 28% protein feed containing 25% soybean meal appears to support maximum growth of hybrid catfish without marked impact on FCR and processed yield.

Experiment 4

Dry matter apparent digestibility coefficients (ADCs) were similar among corn by-products (corn gluten feed, corn germ meal, and DDGS), ranging from 49.9% to 55.5%, which were significantly lower than 70.7% for soybean meal. This was anticipated because these feedstuffs contain higher levels of fiber than soybean meal (Table 7). Energy ADCs followed the same pattern as dry matter ADCs. Corn by-products had similar energy ADCs, ranging from 52.2–58.5%, which were significantly lower than the energy ADC for soybean meal (79.2%). Energy ADCs of 72–73% for soybean meal have been previously reported for channel catfish (Cruz 1975; Wilson and Poe 1985). Protein ADC for soybean meal was 94.2%, similar to the value (93%) previously reported for channel catfish by Wilson and Poe (1985), but higher than 84–85% reported by Cruz (1975) and Brown et al. (1985). Protein ADC for CGF was 77.1%, lower than 88.1% reported by Kitagima and Fracalossi (2011). Corn germ meal and DDGS had protein ADCs of 83.7% and 86.2%, respectively for channel catfish.

Although channel catfish require 10 essential amino acids for normal growth and metabolism, in feed formulation using common practical feed ingredients, only two essential amino acids need to be considered—lysine and

Table 6. Mean production and processing characteristics and fillet proximate composition of pond-raised hybrid catfish fed experimental diets for 184 days in Experiment 3.[1]

	Soybean meal level (%)					Pooled SE	P
	40	30	25	20	15		
Total feed fed (lb/acre)	9,239	9,141	9,307	9,548	9,884	294	0.42
Net yield (lb/acre)	6,737	6,402	6,474	6,479	6,621	234	0.85
Weight gain[2] (lb/fish)	1.22	1.22	1.22	1.23	1.18	0.03	0.88
Feed conversion ratio	1.44 c	1.50 b	1.51 b	1.55 ab	1.57 a	0.02	< 0.01
Survival (%)	87.9	83.6	85.0	84.1	89.4	2.3	0.36
Carcass yield[3] (%)	70.4 a	69.9 abc	70.2 ab	69.7 bc	69.5 c	0.2	0.02
Fillet yield (%)	36.6 ab	36.5 ab	36.8 a	36.2 bc	35.7 c	0.2	< 0.01
Fillet protein[4] (%)	17.5	17.2	17.4	17.2	17.1	0.1	0.19
Fillet fat[4] (%)	6.7	6.6	7.4	6.9	6.5	0.4	0.62

[1]Means within each row followed by different letter differ ($P \leq 0.05$).
[2]Initial weight was 55 pounds per 1,000.
[3]Skin-on carcass yield.
[4]Wet-tissue basis.

sulfur-containing amino acids (methionine and cystine), which are the most limiting amino acids for channel catfish.

Soybean meal had an apparent availability coefficient (AAC) of 93.8% for lysine and 89.2% for methionine, similar to the values (90.9% and 85.8%, respectively) reported by Wilson et al. (1981). In this study, corn gluten feed had an AAC of 67.1% for lysine and 69.1% for methionine, which were lower than 76.0% for lysine and 91.6% for methionine reported by Kitagima and Fracalossi (2011). Corn germ meal had an AAC of 77.6% for lysine and 80% for methionine, and DDGS had an AAC of 72.1% for lysine and 84.8% for methionine for channel catfish.

Corn gluten feed and DDGS had phosphorus AACs of 74.5% and 77.4%, respectively, significantly higher than 36.2% for soybean meal. This is likely because the wet milling and fermentation processes that result in these by-products degrade the phytate form of phosphorus (Kumar et al. 2010; Liu 2011), making it more available to the fish. It appears that phosphorus AACs of feed ingredients for channel catfish are generally correlated to their nonphytate phosphorus levels. Results from this experiment can be useful in formulating cost-effective catfish feeds using these alternative feedstuffs.

Table 7. Mean apparent digestibility/availability coefficients (%) of dry matter, protein, lipid, energy, lysine, methionine, cysteine, and phosphorus in test ingredients for channel catfish. [1, 2]

	SBM	DDGS	CGF	CGM	Pooled SE	P
Dry matter	70.7 a	50.8 b	49.9 b	55.5 b	3.2	< 0.01
Crude protein	94.2 a	86.9 b	74.6 c	83.7 b	1.8	< 0.01
Crude lipid	96.8	93.8	92.8	91.9	2.3	0.58
Energy	79.2 a	58.5 b	52.3 b	57.0 b	3.1	< 0.01
Lysine	93.8 a	72.1 bc	67.1 c	77.6 b	2.9	< 0.01
Methionine	89.2 a	84.8 ab	69.1 c	80.0 b	2.0	< 0.01
Cystine	91.1 a	81.7 b	72.9 c	78.4 b	1.6	< 0.01
Phosphorus (P)	36.2 b	77.4 a	74.5 a	ND[3]	1.9	< 0.01
Nonphytate P (% of diet)	24.1	73.7	75.2	39.1		

[1]Means within each row followed by different letter differ ($P \leq 0.05$).
[2]SBM = soybean meal; DDGS = distillers dried grains with solubles (from corn); CGF = corn gluten feed; CGM = corn germ meal.
[3]Not determined.

CONCLUSIONS

(1) About 25% soybean meal appears to be optimum in a 28% protein, all-plant feed without marked impacts on growth, FCR, or processing yield of pond-raised catfish. The remaining dietary protein can be supplied by alternative feedstuffs such as cottonseed meal, corn gluten feed, or corn germ meal.

(2) Corn by-products (corn gluten feed, corn germ meal, and DDGS) have lower digestibility/availability for protein, energy, lysine, and methionine, but higher phosphorus availability than soybean meal.

(3) Phosphorus availability of feed ingredients for catfish is generally correlated to their nonphytate phosphorus levels.

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