UTILIZATION OF DISTILLER'S DRIED GRAINS WITH SOLUBLE IN

CATFISH FEEDS

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UTILIZATION OF DISTILLER'S DRIED GRAINS WITH SOLUBLE IN CATFISH FEEDS

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CATFISH FEEDS

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Ping Zhou was born in August 16, 1970 in China. He received his bachelor degree in Medical radiology from Wuhan University, Wuhan, China in 1992. After completion of his degree, he worked as a technical radiologist in the Chinese Traditional Medical Hospital of Hubei province for four years and as a radiological physician for eight more years in the same hospital. He married Ying Si, a plant scientist, in 2002 and had his daughter Ariel Zhou in 2003. In 2004, he came to Auburn, Alabama, US following his wife and immediately felled in love with this nice small town. Consequently, he decided to accompany his wife for more years in US. Since the interest of fish, he entered master program under the direction of Dr. D. Allen Davis in Fisheries and Allied Aquaculture, Auburn University in 2007.

THESIS ABSTRACT

UTILIZATION OF DISTILLER'S DRIED GRAINS WITH SOLUBLE IN CATFISH FEEDS

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Feed is generally the largest expenditure in semi-intensive and intensive catfish culture operations, and protein is the most expensive component of feeds. Efforts to reduce feed costs have resulted in increased use of plant proteins in diet formulations as replacements of expensive animal ingredients. Currently, soybean meal (SBM) comprises 30 to 40% in commercial grow-out feeds for catfish. Replacement of SBM with less expensive protein sources would be beneficial in reducing feed costs. Distiller's dried grains with solubles (DDGS), a co-product of the ethanol distillery industry, is less expensive than SBM on a per unit protein basis. In 2001, the U.S. produced about 3.1 million tons of DDGS. As a result of the recent expansion and increase in ethanol production for fuels due to the shortage and rising cost of petroleum-based fuel, and to reduce pollution , the production of DDGS in the U.S. has been reported to increase to approximately 8 million tons in 2006 (Shurson 2006).

To evaluate the effects of the dietary levels of DDGS with and without lysine supplementation on growth, feed intake, feed efficiency of a catfish growth trial, two different catfish spices were chosen, channel catfish (*Ictalurus punctatus)* and hybrid catfish (channel catfish × blue catfish *Ictalurus furcatus*). Channel catfish were reared in earth pond and hybrid catfish in an indoor intensive water reuse system using the same formulation of five different feeds. Five diets (diets 1-5) were formulated to contain approximately 32% crude protein and 2,900 kcal of digestible energy/kg (NRC 1993). The diets were consisted of a basal (control) diet and diets containing 20 and 30% DDGS, with and without the addition of lysine to the level equal to that of the basal diet. The test diets were formulated as partial replacements of a mixture of soybean meal (SBM) and corn meal (CM) on an equal protein basis. Lipid levels in all diets were maintained constant by the addition of fish oil. Diets were processed into floating pellets by a local Feed Mill.

Based on statistical analysis of the result, there are no significant difference among all treatments for the measured parameters in both species including survival rate, weight gain, feed intake, FCR, final size etc. Under the reported conditions, lysine supplementation may be omitted from theses diet formulations for channel catfish reared in earthen pond conditions and hybrid catfish reared in intensive system. Consequently, the feed cost in channel catfish production as well as hybrid catfish production can be further reduced by omitting the lysine supplementation for these formulations. Based on these results further research should focus on challenges using higher levels of DDGS as well as the possibility of immune stimulation by DDGS.

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I. INTRODUCTION

According to the UN Food and Agriculture Organization, aquaculture is growing more rapidly than all other animal food-production sectors (FAO 2006). Its contribution to global supplies of fish, crustaceans and molluscs increased from 3.9% of total production by weight in 1970 to 32% in 2005 and is currently estimated at 50% of the world supply. This growth is at an average compounded rate of 9.2% per year since 1970, compared with only 1.4% for capture fisheries and 2.8% for terrestrial farmed-meat production systems. It is remarkable that half of the consumed seafood in the world is now farm raised.

The expansion of aquaculture production has been accompanied by a rapid growth of feed production for aquatic species. The challenge facing the aquaculture industry is to identify economically viable and environmentally friendly feeds to rear fish. Presently, many of our feeds are based on the use of fish meal and fish oil. While the supply of fish meal and oil in world supplies cannot be expand, Hence, as the feed industry continues to expand so does the demand for marine ingredients. The feeds industry has recognized for many years that viable utilization of plant based feedstuffs formulated into feeds for the production of cold-, cool- and warm-water aquatic species is an essential requirement for future development of aquaculture as well as current cost savings.

Continued growth and intensification of aquaculture production depends upon the development of sustainable protein sources that are economical and from expandable supplies. There are various plant feedstuffs which currently are or potentially may be incorporated into feeds to support the sustainable production of various fish species in aquaculture.

The use of fishmeal in fish feeds varies considerably due to a variety of factors including, ingredient costs, nutrient requirements as well as farm requests. Of the alternative protein sources, soybean products such as solvent extracted soybean meal (SBM) is one of the most important plant based proteins as it has a suitable nutrient content and ready supply (Gatlin & Barrows 2007). As compared to fish meal, SBM is a relatively inexpensive protein source and there are a number of fish species (e.g. carp, tilapia and catfish) whose diets are primarily derived from SBM. Over the years, the price of soybean has generally increased. Thus, in diets formulated primarily with SBM, to further reduce costs, one has to look at alternatives to reduce the use of SBM in the diet. There are some products such as cottonseed meal (CSM) and distiller's dried grains with solubles (DDGS) which can be used as substitute ingredients.

The use of plant based diets varies considerably from species to species. Farm-raised channel catfish (*Ictalurus punctatus*), is the most important aquaculture industry in the United States, representing about half the total United States aquaculture production. The catfish industry is one that is very mature and considerable nutrition work has been conducted with this species resulting in very efficient and low cost production diets. In fact, catfish feeds are some of the least expensive feeds in the industry as they are primarily based on soybean meal as the primary protein source.

Channel catfish is typically fed a diet comprised primarily of soybean meal (SBM), corn, and wheat middlings plus a small amount of animal meal, fat, and nutrient supplements (Robinson et al. 2001). Like other animals, catfish do not have an absolute protein requirement, but rather have a requirement for indispensable amino acids and a certain amount of nonspecific nitrogen for normal growth. Dietary protein requirements for catfish have been determined in various studies, and range from 24 to 55% (NRC 1993). The wide variation in protein requirements for catfish is not surprising because of the different conditions under which the studies were conducted and the fact that several factors affect the dietary protein requirement. Fish of different size and life stages require different levels of dietary protein for maximum growth. Catfish fry raised from swim-up to about 2 to 3 weeks of age require about 55% protein in the diet for normal growth (Winfree & Stickney 1984). Catfish fingerlings raised from about 10 to 25 cm (4 to 10 inches) length require 35% dietary protein for maximum growth, while a diet containing 25%-35% protein can be adequate for fish grown from 100 to 500g (0.25 to 1.1 pound) (Page & Andrews 1973).

Digestible energy of the diet maybe also influences the dietary protein requirement. It has been demonstrated that small catfish grow as well on a 27% protein diet as on a 38% protein diet when the energy level in the diet is low, but when the energy level increases, feed consumption decreases and the low protein diet does not support maximum growth (Manfalik 1986).

Feeding rate may have a profound effect on the dietary protein requirement. Minton (1978) reported that weight gain of pond-raised catfish was not different when the fish were fed to satiation with 30% and 36% protein diets, but feeding at approximately 75% of satiation the fish fed the 36% protein diet gained more weight. Similarly, Li and Lovell (1992) reported that a dietary protein concentration of 26%

was adequate for optimum weight gain when fish were fed as much as they would consume, whereas a minimum dietary protein level of 32% was necessary for optimum growth when fish were fed at a predetermined maximum level of 60 kg/ha (55 pounds/acre) per day.

Dietary protein requirements for catfish are also influenced by the presence of natural food organisms in pond water. Although the natural food organisms are abundant in catfish ponds, the contribution to growth is relatively small. Wiang (1977) reported that only 2.5% of the protein requirement and 0.8% of the energy needed for catfish grown at a moderate density in ponds were obtained from natural foods. However, there are indications that natural foods are significant sources of micro-nutrients, such as vitamins, minerals, and essential fatty acids (Robinson et al. 1998).

Feed is generally the largest expenditure in semi-intensive and intensive catfish culture operations, and protein is the most expensive component of feeds. Efforts to reduce feed costs have resulted in increased use of plant proteins in diet formulations as replacements of expensive animal ingredients. Soybean meal (SBM), because of its consistent quality and availability, and high nutritional value, is the most commonly used plant ingredient in fish feeds. Currently, SBM comprises 30 to 40% in commercial grow-out feeds for catfish. Replacement of SBM with less expensive protein sources would be further beneficial in reducing feed costs or providing alternatives to the feed mill manager. Considerable work has been conducted on cotton seed meal, peanut meal as well as DDGS, another cost effective alternative.

Distiller's dried grains with solubles (DDGS), a co-product of the ethanol distillery industry, although currently not locally available, may become abundant as ethanol plants come on line as a result of new energy policies and an abundant corn crop in the southern United States. In 2001, the U.S. produced about 3.1 million tons of DDGS. As a result of the recent expansion and increase in ethanol production for fuels due to the shortage and rising cost of petroleum-based fuel, and to reduce pollution , the production of DDGS in the U.S. were reported to have increased to approximately 8 million tons in 2006 (Shurson 2006).

DDGS has a moderate level of protein (~ 30% crude protein) without the presence of antinutritional factors commonly found in most plant protein sources. Moreover, the yeast component of DDGS also contains β-glucan and mannans which have been reported to stimulate fish immune responses (Lim 2008). This product has been successfully used in commercial catfish feeds and experimental diets at levels of 15–30% as a replacement for animal proteins and SBM (Webster et al. 1991; Robinson et al. 2001). DDGS are highly palatable to catfish but contain about 45% of the lysine found in SBM. Research has shown that all the animal protein in catfish diets can be replaced with SBM, and a portion of the SBM can be replaced by other plant proteins such as DDGS (Robinson & Li 2008).

Presently, DDGS is widely used as a protein supplement in terrestrial animal feeds, but its use in fish feed is limited due to its low content of essential amino acids, especially lysine (NRC 1993). Results of earlier studies, however, have shown that based on growth performance and feed utilization efficiency, DDGS is a promising feed ingredient for several fish species, including rainbow trout (Cheng & Hardy 2004), channel catfish (Lovell 1980; Tidwell et al. 1990; Webster et al. 1991, 1992a, 1992b, 1993), and tilapia (Wu et al. 1996; Lim et al. 2007). A recent laboratory study by Lim and co-workers (personal communications) showed that, with lysine supplementation, DDGS at dietary levels ranging from 10 to 40% can be used in catfish feeds as replacements of various levels of a mixture of SBM and corn meal without affecting their growth and feed utilization efficiency. Because of the shortage of lysine in DDGS, practical feeds used for catfish production containing DDGS will most likely require lysine enhancement.

There have been a number of studies evaluating the use of DDGS in catfish feeds. A diet containing 15% DDGS has been reported to provide satisfactory growth of channel catfish (Hastings 1967). Lovell (1980) reported that, when used in combination with 10% fish meal, up to 30% DDGS can be used in channel catfish diets. Webster et al. (1993) also found that 30% DDGS can be used as a replacement of a mixture of SBM and CM (corn meal) in channel catfish diets containing 8% fish meal. Tidwell et al. (1990) and Webster et al. (1991) found that 40 and 35% DDGS, respectively, can be used in catfish diets as substitutes for the combination of SBM and CM on an equal protein basis without requiring lysine supplementation. However, a diet containing 70% DDGS appeared to be deficient in lysine because supplementation of lysine at a level to meet lysine requirement improved the growth of catfish (Webster et al. 1991). In another study, evaluating fixed percentage of DDGS (35%) and variable percentages of SBM (35–49%) as a partial or total replacement of fish meal in channel catfish diets, Webster et al. (1992a) found that the weight gain of fish fed the diet with 0% fish meal, 35% DDGS, and 49% SBM was similar to that of the diet with 12% fish meal and 48% SBM. Although, there are a number of studies evaluating the use of moderate levels of DDGS in conjunction with feed formulations using fish meal, there are few trials evaluating the response using the upper limits of DDGS.

The catfish industry is critical to the economy of a number of states such as Mississippi and Alabama. The industry is evaluating a variety of alternatives to make them more cost competitive. Reducing the feed costs is just one of the strategies. Using other catfish species could be a way to be more economically competitive. At least four species of ictalurid catfish and several hybrids have been considered as candidates for commercial aquaculture in the USA. Channel catfish *Ictalurus punctatus* and blue catfish *I. furcatus* are the best two species for aquaculture (Tucker & Robinson, 1990; Dunham et al., 1993). Compared with blue catfish, the channel catfish has faster growth-to-market size, better tolerance for low oxygen, and superior resistance to some diseases (such as columnaris). However, blue catfish has superior resistance to certain diseases (such as enteric septicemia of catfish), better carcass traits, and easier harvest ability (Dunham & Argue, 2000). Research on hybrids, female channel catfish *I. punctatus* × male blue catfish *I. furcatus* (C×B), has demonstrated that they exhibit many commercially desirable characteristics. Compared to most commercially cultured strains of channel catfish, the C×B hybrid exhibits superior characteristics for the following traits: faster growth, tolerance of low oxygen, increased resistance to many diseases, tolerance to crowded growth conditions in ponds, uniformity in size and shape, higher dress out percentages, increased harvest ability by seining, and increased vulnerability to angling (Wolters et al., 1996; Masser & Dunham, 1998).

The use of hybrid catfish has become more and more common in catfish industry and the nutrition studies related to hybrid catfish are very limited. It is demonstrated that the growth and feed conversion ratio (FCR) were better for C×B hybrid fed the 25% protein diet compared to those fed the 45% protein diet (Bosworth et al., 1998).

The economic challenges from lower and lower price of catfish product forced today's catfish industry in the US to reduce the feed cost as more as possible and also find more economically competitive species. The use of higher level of DDGS to replace SBM without lysine supplementation may be a way to further lower feed cost.

As discussed, there is considerable interest in the use of DDGS in both traditional catfish culture and hybrid catfish culture. Currently, there is considerable laboratory work on the use of DDGS in channel catfish feeds. However, there are few examples which demonstrate the feasibility of using high levels of DDGS with or without lysine supplements under pond production conditions. Consequently, the primary objective of this work was to evaluate the response of channel catfish to diets containing 20 or 30% DDGS with or without lysine supplements in pond production condition. As an alternative species to channel catfish in today's catfish industry, hybrid catfish production has become more and more popular in US. As mentioned before, there is limited information on hybrid catfish nutrition and their acceptance of practical diet formulations. So the secondary objective of this research was to preliminarily evaluate the response of fingerling hybrid catfish to the four mentioned diets under controlled laboratory conditions.

II. UTILIZATION OF CATFISH PRODUCTION DIETS USING HIGH LEVELS OF DDGS WITH OR WITHOUT LYSINE SUPPLEMENTS

1. ABSTRACT

The response of channel catfish to practical diets containing 20% and 30% DDGS with and without lysine supplementation was evaluated over a 150 day pond trial. Twenty earthen ponds four replicates per treatment were stocked with 650 juvenile channel catfish. The control diet (Diet-1) contained 35% SBM and 23.7% CM was based on the formula of a practical diet for channel catfish. The experimental diets included: Diet-1 (basal diet; no DDGS and no lysine supplementation), Diet-2 (20% DDGS and 0% lysine supplementation), Diet-3 (20% DDGS and 0.10% lysine supplementation), Diet-4 (30% DDGS and 0% lysine supplementation) and Diet-5 (30% DDGS and 0.20% lysine supplementation). There were no significant differences among all treatments for the measured parameters including initial weight, initial biomass, initial length, final number, final weight, final biomass, final average length, weight gain, yield, feed input, survival rate, and FCR. This study indicates that diets without lysine supplementation containing 30% DDGS in combination with SBM and CM provide good growth and feed utilization in channel catfish pond production.

2. INTRODUCTION

Feed is generally the largest expenditure in semi-intensive and intensive catfish culture operations, and protein is the most expensive component of feeds (Robinson & Li, M 2008). Efforts to reduce feed costs have resulted in increased use of plant proteins in diet formulations as replacements of expensive animal ingredients. Soybean meal (SBM), because of its low-cost, consistent quality, availability, and high nutritional value, is the most commonly used plant based protein source in fish feeds. Currently, SBM comprises 30 to 40% of the formulation in commercial grow-out feeds for catfish. Replacement of SBM with less expensive protein sources would be beneficial in reducing feed costs. Distiller's dried grains with solubles (DDGS), a co-product of the ethanol distillery industry, is typically less expensive than SBM on a per unit protein basis. In 2001, the U.S. produced about 3.1 million tons of DDGS. As a result of the recent expansion and increase in ethanol production for fuels due to the shortage and rising cost of petroleum-based fuel, and to reduce pollution , the production of DDGS in the U.S. has been reported to approximately 8 million tons in 2006 (Shurson 2006).

DDGS has moderate protein content (~ 30% crude protein) without the presence of antinutritional factors commonly found in most plant protein sources. At present, DDGS is widely used as a protein supplement in terrestrial animal feeds, but its use in fish feed is limited due to its low content of essential amino acids, especially lysine (NRC 1993). Results of earlier studies, however, have shown that based on growth performance and feed utilization efficiency, DDGS is a promising feed ingredient for several fish species, including rainbow trout (Cheng and Hardy 2004), channel catfish (Lovell 1980; Tidwell et al. 1990; Webster et al. 1991, 1992a, 1992b, 1993), and tilapia (Wu et al. 1996; Lim et al. In Press). A recent laboratory study by Lim and co-workers (personal communications) showed that, with lysine supplementation, DDGS at dietary levels ranging from 10 to 40% can be used in catfish feeds as replacements of various levels of a mixture of SBM and corn meal without affecting their growth and feed utilization efficiency. The cost of feed can be further reduced if lysine supplementation can be omitted from the formulation.

Currently, there is considerable interest in the use of DDGS in commercial catfish rations. However, there is limited information on the use of high levels DDGS and the need for lysine supplements. Hence, the objective of this study was to demonstrate 1) the use of DDGS at high inclusion levels and 2) to determine if lysine supplements are required in commercially grow out DDGS containing diets for channel catfish.

3. MATERIALS AND METHODS

3.1. PONDS

Twenty rectangular ponds were utilized at the E. W. Shell Fisheries Center, North Auburn. The size of each pond is equally 0.04 ha (0.1 acre), and from 0.6-1.2 m (2 to 4 feet) in depth with a bottom slope of 0.2 to 0.3 degree. A rectangular catch basin is situated in the deep end of the pond and contains a water inlet and tilt down screened stand pipe. Each pond has two separate water supply lines for independent filling from the catch basin or the shallow end of the pond. Ponds were sun dried for one week before stocking. They were then filled with around 0.6 m (2 feet) of water and copper sulfate was applied for 4 days to prevent the aquatic weeds problems. The ponds were then drained, dried for two days, filled and quick lime applied to increase the alkalinity of the water. Ponds were filled from a hillside reservoir receiving runoff from the stations water shed.

3.2. DIETS PREPARATION

Five experimental diets were formulated to contain 32% protein and 6% lipid. The upper limit to dried distiller's grain with soluble (DDGS) was set at 30% due to processing consideration and possible degradation of pellet quality when using higher inclusion levels (Lim 2007). The diets consisted of a basal (control) diet and test diets containing 20% and 30% DDGS, with and without the addition of lysine. The DDGS replaced on an equal protein basis a mixture of SBM and CM. (Table 2). The diets were designated as follows: Diet-1 (basal diet; no DDGS and no lysine supplementation), Diet-2 (20% DDGS and 0% lysine supplementation), Die-3 (20% DDGS and 0.10% lysine supplementation), Diet-4 (30% DDGS and 0% lysine supplementation) and Diet-5 (30% DDGS and 0.20% lysine supplementation). Fish oil was adjusted to keep lipid constant in all treatments. Because DDGS contains lower levels of protein than SBM, a combination of SBM and CM was used to maintain the protein level around 32%. Diets were extruded into floating pellets by Zeigler Brothers Inc. (Gardners PA, USA) and were transported and stored in plastic lined paper bags. A pooled sample from over > 15 bags was collected and the proximate composition and amino acids composition of the diets analyzed following AOAC (1995) procedures by the New Jersey Feed Laboratory, Inc and are presented in Table 1 and 2, respectively.

3.3. CULTURE METHODS

Channel catfish (*Ictalurus punctatus*) juvenile were obtained from a commercial fingerling producer in Mississippi. Before juveniles were stocked into experimental ponds, a formalin treatment was applied to reduce disease transmission in holding troughs. An initial sample of 60 fingerlings was randomly collected for the calculation of average initial weight, length, and size distribution. Based on the relationship between weight and length, all juveniles were judged as thin (relative weight ratio of every fish is less than 1.0). The standard length-weight relationship comes from the published values of Tucker & Hargreaves (2004).

Juveniles were manually sorted into three groups based on length. The range for each group was: less than 12.7cm (5 in), 12.7-15.2 cm (5-6 in), larger than 15.2cm (7 in). Every group was then evenly stocked into twenty ponds in a rate of 650 fish per pond (6500/acre or 16055/ha). During the first five days after stocking, mortalities were collected and replaced with similar sized fish.

Feed was offered once a day in the afternoon. A fixed quantity of feed was pre-weighed for each pond which was based on an estimated feed intake. Feed was then offered to satiation with daily rations adjusted as needed based on the fishes response and the desire not to over feed The feeding process in this study was:

1. Pre-weight feed for each pond.
2. Apply feed to pond slowly and observe the feeding behavior.
3. Increase or decrease feed inputs based on feeding response.

Table 1. Ingredient and proximate composition of five experimental diets (As is basis)

Ingredient	Diet-1	Diet-2	Diet-3	Diet-4	Diet-5
Soybean meal	32.00	24.00	24.00	20.00	20.00
DDGS[1]	0.00	20.00	20.00	30.00	30.00
Wheat middlings	21.79	16.00	16.00	9.99	9.79
Corn meal	20.00	15.00	15.00	16.00	16.00
Cottonseed meal	15.00	14.99	14.89	15.00	15.00
Poultry by product meal 67% P	5.60	5.40	5.40	5.40	5.40
Blood meal 92% P	2.00	2.00	2.00	2.00	2.00
Fish oil	2.00	1.00	1.00	0.00	0.00
Dicalcium phosphate	1.00	1.00	1.00	1.00	1.00
Ca propionate	0.25	0.25	0.25	0.25	0.25
Vitamin premix[2]	0.20	0.20	0.20	0.20	0.20
Mineral premix[2]	0.10	0.10	0.10	0.10	0.10
Stay-C 35% active	0.06	0.06	0.06	0.06	0.06
Lysine	0.00	0.00	0.10	0.00	0.20
Proximate composition (As is basis)[3]					
Crude protein	35.0	34.2	34.8	35.0	34.0
Crude lipid	6.8	6.6	6.6	7.1	6.6
Fiber	5.5	5.7	5.8	5.8	5.9
Ash	6.3	6.2	6.2	6.1	5.7
Lys % Protein	5.4	5.0	5.1	4.7	4.8
Met + Cys % Protein	3.4	3.6	3.5	3.5	3.3

[1] *DDGS: distiller's dried grains with solubles.*
[2] *Vitamin and mineral premixes (DSM Inc., 45 Waterview Boulevard, Parsippany, New Jersey 07052-1298).*
[3] Analysis conducted by New Jersey Feed Lab Inc 1686 Fifth St Trenton NJ. 08638

Table 2. Amino acid compositions (g/100g basis) of the experimental diets Analysis conducted by New Jersey Feed Lab Inc , Trenton NJ. USA.

Amino acids (% dry diet)	Diet-1	Diet-2	Diet-3	Diet-4	Diet-5
Methionine	0.60	0.62	0.62	0.61	0.58
Cystine	0.55	0.55	0.55	0.55	0.51
Lysine	1.81	1.63	1.67	1.58	1.58
Phenylalanine	1.69	1.65	1.69	1.67	1.67
Leucine	2.63	2.73	2.85	2.90	3.00
Isoleucine	1.28	1.22	1.36	1.30	1.29
Threonine	1.32	1.28	1.28	1.32	1.28
Valine	1.52	1.48	1.59	1.57	1.50
Histidine	0.88	0.89	0.87	0.88	0.87
Arginine	2.56	2.28	2.41	2.31	2.33
Glycine	1.82	1.71	1.72	1.77	1.68
Aspartic acid	3.61	3.34	3.35	3.33	3.22
Serine	1.77	1.71	1.68	1.72	1.66
Glutamic acid	6.49	6.54	6.19	6.59	6.36
Proline	1.81	1.95	1.91	2.08	1.97
Hydroxyproline	0.20	0.22	0.23	0.23	0.24
Alanine	2.07	2.00	2.19	2.31	2.04
Tyrosine	0.84	0.87	0.90	0.86	0.89
Total	33.45	32.67	33.06	33.58	32.67

Water temperature and DO concentrations were monitored twice daily (at about 06:00 and 17:00 h) using an YSI model 55 DO meter (YSI Incorporated). Water sample were collected every two weeks for total ammonia nitrogen analysis and pH was checked every week using pH test strips. Morning DO levels of ponds were maintained above 3 ppm by using 0.5-hp floating vertical pump aerators.

3.4. HARVESTING AND FINAL DATA COLLECTION

The fish were cultured from May 22, 2008 to October 21, 2008 with feed being offered over 150 days. Prior to harvest, the water level was lowered to 2 feet for all ponds. The harvest process included group weighing of the fish with 40 fish randomly sampled for the determination of individual weights and lengths. Fish were first removed by seining the ponds then by drain harvesting with the fish concentrated into the catch basin. After harvest, five fish from each pond was collected for determination of whole-body proximate composition (AOAC 1990). The collected data including: final number, final weight, final biomass, final average length, weight gain, and yield. Survival was in percentage basis. FCR was the ratio of feed input over yield.

The collected data was then analyzed for statistical differences using SAS (Statistic Analysis Systems, SAS Institute, Inc., Cary, NC, 2008). Data was analyzed by one-way analysis of variance and Student-Nuewman-Keuls test to determine significance ($P \leq 0.05$) difference between means.

4. RESULTS

Overall means ($\pm$ 95% confidence interval) for water quality parameter were: temperature, 26.5 $\pm$ 0.2^{o}C; dissolved oxygen, 4.84 $\pm$ 0.06 ppm; pH, 7.8 $\pm$ 0.3; total ammonia nitrogen, 0.24$\pm$0.03 ppm; (ranged from 0 to 1.48 ppm). These values are within acceptable water quality criteria (Table 3) for channel catfish grow out pond provided by Craig S. Tucker (Tucker 2004).

Initial biomass, initial weight, final biomass, final weight, net yield, final number, survival, weight gain, feed consumption, and FCR are summarized in table 4. Survival rate ranges from 62% to 85%. The numerically lowest survival rate was found in diet 2 which is 20% DDGS diet without lysine supplementation. The highest survival rate was found in diet 5 which is 30% DDGS diet with 0.2% lysine supplementation. Percent weight gain (WG) ranges from 243.9% to 397.5%. The lowest number of WGR was found in diet 2 which is 20% DDGS diet without lysine supplementation and the highest number of WGR was found in diet 3which is 20% DDGS diet with 0.1% lysine supplementation. FCR ranges from 1.5 to 2.2. The lowest FCR was found in diet 3 (20% DDGS + 0.1% lysine) and the highest FCR was found in diet 2 (20% DDGS + 0% lysine). There are no significant differences were found in recorded parameter among all diets including initial number, initial weight, initial size, final number, final weight, final size, survival rate, weight gain and final relative weight.

The whole-body proximate composition analysis of sample in harvest is given in table 5. There was no significant difference among the tested parameters.

5. DISCUSSION

Dietary protein requirements for catfish have been determined in various studies, and range from 24 to 55% (NRC 1993). As mentioned before, factors that can influent the protein requirements for catfish were concluded as: 1) Different size and life stages. 2) The digestible energy content of the diet. And 3) Feeding rate. Li and Lovell (1992) reported that a dietary protein concentration of 26% was adequate for optimum weight gain when fish were fed as much as they would consume, whereas a minimum dietary protein level of 32% was necessary for optimum growth when fish were fed at a predetermined maximum level of 60 kg/ha (55 pounds/acre) per day. In present study, all diets were maintained to have a protein level around 32%. This protein level was chosen as it is currently used by the commercial industry in Alabama.

Table 3. Acceptable Water Quality Criteria for a catfish grow out pond (Tucker & Hargreaves 2004).

1. Temperature range 20^0C-35^0C, ideal range: 25^0C-32^0C
2. Low CO_2 , less than 5 ppm, no more than 20 ppm
3. Morning O_2 - more than 3 ppm less than 1 ppm lethal
4. Nitrogen (gas)
   - 100% saturation acceptable
   - supersaturation problems
5. Suspended solids- < 2000 ppm
6. pH- 6.5-9.0
7. Alkalinity and hardness 50 mg to 250 mg/L Ca as $CaCO_3$
8. Salinity : lower than 12ppt
9. Iron- less than 0.1 ppm
10. Pesticides/pollution free

In order to reduce the cost of production diets for catfish, one could either reduce the level of protein, which is not favorable by many producers, or one could switch to a lower cost protein source. DDGS is one of the choices which are the lower cost protein source. DDGS has moderate protein content (~30% crude protein) without the presence of antinutritional factors commonly found in most plant protein sources. At present, DDGS is widely used as a protein supplement in terrestrial animal feeds, but its use in fish feed is limited due to its low content of essential amino acids, especially lysine (NRC 1993). Results of earlier studies, however, have shown that based on growth performance and feed utilization efficiency, DDGS is a promising feed ingredient for several fish species, including rainbow trout (Cheng & Hardy 2004), channel catfish (Lovell 1980; Tidwell et al. 1990; Webster et al. 1991, 1992a, 1992b, 1993), and tilapia (Wu et al. 1996; Lim et al. 2008).

Table 4. Growth performance and feed utilization of channel catfish fed on experimental diets. (Statistic Analysis Systems, SAS Institute, Inc., Cary, NC, 2008).

	Diet-1	Diet-2	Diet-3	Diet-4	Diet-5	PSE	P-value
IBio(kg)	56.3	56.9	55.7	56.3	55.9	0.67	0.787
IW(g)	86.7	87.5	85.7	86.7	86.1	1.03	0.786
FBio(kg)	236.3	229.2	251.8	234.0	233.4	9.64	0.535
Yield(kg/ha)	5838	5661	6220	5779	5766	238.1	0.535
NetY(kg/ha)	4446	4255	4844	4388	4383	231.7	0.472
FNum	477.0	476.8	523.0	476.5	499.8	22.36	0.512
Sur(%)	73.5	73.2	80.2	73.3	77.0	0.035	0.548
FW (g)	498.8	481.7	482.2	491.4	468.6	17.78	0.799
NYP(kg)	180.0	172.3	196.1	177.7	177.5	9.38	0.472
WG (%)	319.5	302.8	351.8	315.5	317.0	15.4	0.30
MRW	1.16	1.11	1.11	1.10	1.13	0.019	0.148
FC(kg)	310.5	327.7	327.1	332.2	333.2	7.6	0.27
FCR	1.7	1.9	1.7	1.9	1.9	0.077	0.151

IBio: Initial Biomass (kg)
IW: Average Initial Weight (g)
FBio: Final Biomass (kg)
*Yield: FBio*10*2.47acre/hectare (kg/ha)*
*NetY:(Fbio – Ibio) *10*2.47acre/hectare(kg/ha)*
FNum: Final Number
Sur:Average Percent Survival (%)
FW: Average Final Weight (kg)
NYP: Net yield per pond = FBio- IBio (kg)
WG: Weight gain = 100 × (final weight – initial weight) / initial weight (%)
MRW: Mean relative weight: Mean relative weight of 40 fish per pond.
FC: Average Feed Consumption per pond (kg)
FCR: Feed conversion ratio = feed offered (kg) / weight gained (kg)
PSE: Pooled standard Error=$\sqrt{MSE/n}$

Table 5. Whole-body proximate composition of channel catfish fed diets containing various levels of distiller's dried grains with solubles with and without lysine supplementation for 150 days.

diet	Moisture (%)	Percent wet weight basis (%)		
		Lipid	Ash	Protein
1	74.85	6.11	1.18	17.75
2	75.46	5.26	1.15	17.60
3	74.89	5.82	1.17	17.54
4	75.53	5.44	1.18	17.53
5	74.51	6.35	1.18	17.83
PSE	0.577	0.573	0.023	0.23
p-value	0.689	0.653	0.791	0.85

The present study was conducted over a 150 days of culture resulting in a final biomass of around 5550 kg/ha (5000 lbs/acre). These numbers are typically acceptable in the southern US (Tucker 2004). Results of the present study suggest that utilization of high levels (20% and 30%) of DDGS in production diets for catfish is acceptable. Under the conditions of this study, there were no differences in net yield, final weight and FCR for fish reared on a typical catfish feed or one containing 20% and 30% DDGS. These results are supported by a number of other studies with various fish species and under variety of culture conditions.

Wu et al. (1996), in a study to evaluate the growth response of Nile tilapia *(Oreochromis niloticus)* fry fed all-plant protein diets, reported that in diets containing 32, 36, and 40% crude protein, incorporation of 16–49% DDGS resulted in good WG, FER, and PER. A diet containing 15% DDGS has been reported to provid satisfactory growth of channel catfish (Hastings 1967). Lovell (1980) reported that, when used in combination with 10% fish meal, up to 30% DDGS has been used in channel catfish diets under pond conditions. Webster et al. (1993) also found that 30% DDGS can be used as a replacement of a mixture of SBM and corn meal in channel catfish diets containing 8% fish meal when the fish are reared in cages culture conditions. Tidwell et al. (1990) and Webster et al. (1991) found that 40 and 35% DDGS, respectively, can be used in catfish diets as substitutes for the combination of SBM and CM on an equal protein basis without requiring lysine supplementation. In the same study, Webster also reported that a diet containing 70% DDGS appeared to be deficient in lysine because supplementation of lysine at a level to meet lysine requirement improved the growth of catfish. In a laboratory study of Nile tilapia *(Oreochromis niloticus)*, Lim et al. (2007) reported that increasing dietary levels of DDGS to 40% without addition of lysine significantly reduced WG and PER compare to those obtained with diets containing lower DDGS levels (0, 10, and 20%). FCR of this diet (40% DDGS) was also significantly lower than that of the control diet.

Lysine is generally considered to be the first limiting amino acid for catfish. If feeds are formulated to meet a minimum lysine requirement, the requirements for all other amino acids are met or exceeded if traditional feed ingredients are used. Lysine will likely be the only supplemental amino acid needed in commercial catfish feeds (Tucker and Hargreaves 2004). Lysine requirement of juvenile channel catfish for optimum growth was reported as 5.1% of total protein (NRC 1993). Lysine levels of the test diets are presented in table 2 in diet percentage basis. Converting these values to percentage of dietary protein, the diets lysine percentages of total protein are: diet 1, 5.41%; diet 2, 4.99%; diet 3, 5.05%; diet 4, 4.71%; diet 5, 4.84%. So diet 4 and diet 5 likely have the higher risks to show lysine deficiency. In the present study, signs of a dietary lysine deficiency were not evident.

There are several possible reasons that a deficiency was not observed. One possible explanation is that the fermentation process can improve the digestibility of plant protein sources; thus, improving the availability of lysine. Ingledew (1999) estimated that 3.9% of the total biomass of DDGS was yeast, with 5.3% of the protein content of this product being contributed by yeast protein. Yeasts are rich in protein, B-complex vitamins and β-glucans. Therefore, effects of the micronutrients and some other components of DDGS should be taken into account when it is used as dietary protein source. Another reason could be that DDGS improved the palatability of feed and fish can eat more thus improving daily intake which would over shadow a minor deficiency.

In the present study, as well as those of Tidwell et al. (1990) and Webster et al. (1991) it was demonstrated that high levels of DDGS can be used in catfish diets as substitutes for the combination of SBM and CM on an equal protein basis without requiring lysine supplementation. In addition to growth and production not being influence by the shifts in protein sources there were no differences in proximate composition of the fish. As table 5 shows, whole-body proximate composition was not affected by dietary levels of DDGS and lysine supplementation. The lower protein content of fish fed the 30% DDGS diet without lysine may be related to smaller size of sampled fish that had less flesh. Webster et al. (1992b) reported significantly lower protein content of dressed carcass of catfish fed a diet with 90% DDGS without added lysine than in fish fed the 55% DDGS diet. However, no significant differences were observed among carcass proximate composition of catfish fed diets containing 0, 10, 20, and 30% DDGS (Webster et al. 1993). However, there were significantly lower protein content of dressed carcass of catfish fed a diet with 90% DDGS without added lysine than in fish fed the 55% DDGS diet. If the channel catfish industry is going to reduce costs, they must optimize commercial feed formulations. Hence, when feed prices warrant the use of DDGS there appears to be no reason not to use up to 30% DDGS in practical diets. As this ingredient is low in lysine, levels of this nutrient should be adjusted if needed.

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III. GROWTH RESPONSE AND FEED UTILIZATION OF JUVENILE HYBRID CATFISH, *I. PUNCTATUS* × *I. FURCATUS*, USING HIGH LEVELS OF DDGS WITH OR WITHOUT LYSINE SUPPLEMENTS

1. ABSTRACT

A feeding trial was conducted in aquaria with juvenile hybrid catfish, channel catfish *Ictalurus punctatus* × blue catfish *I. furcatus* (C × B), to evaluate the distiller's dried grains with solubles (DDGS) as a replacement for a combination of soybean meal (SBM) and corn meal (CM). Twenty-five 75 l glass aquaria were stocked with 30 juvenile hybrid catfish (initial weight: 1.16-1.25 g) per aquarium. The control diet (Diet-1) contained 35% SBM and 23.7% CM was based on the formula of a practical diet for channel catfish. The list of the experimental diets was as follows: Diet-1 (basal diet; no DDGS and no lysine supplementation), Diet-2 (20% DDGS and 0% lysine supplementation), Diet-3 (20% DDGS and 0.10% lysine supplementation), Diet-4 (30% DDGS and 0% lysine supplementation) and Diet-5 (30% DDGS and 0.20% lysine supplementation). Fish were restricted-fed at a rate equaling 5-10% of wet body weight twice daily for 8 weeks. There were no significant differences in final weight, final biomass, percentage weight gain (WG) among the all treatments. The lowest feed conversion ratio (FCR) was found in Diet-4. This study indicates that diets without lysine supplementation containing 30% DDGS in combination with SBM and CM provide good growth and feed utilization in juvenile C × B hybrid catfish.

2. INTRODUCTION

Efforts to reduce feed costs have resulted in increased use of plant proteins in diet formulations as replacements of expensive animal ingredients, especially fish meal. Because of its high protein content, high digestibility, relatively well-balanced amino acid profile, reasonable price, and steady supply, solvent extracted de-hydrated soybean meal (SBM) is widely used as a cost-effective feed ingredient for many aquaculture animals (Storebakken et al., 2000). However, other plant protein sources often cost less than SBM, thus replacing SBM with less expensive plant protein sources would be beneficial in reducing feed costs.

Distiller's dried grains with solubles (DDGS) is a co-product of the ethanol distillery industry. As a result of the recent expansion and increase in ethanol production for fuels, and to reduce pollution, the production of DDGS in the USA has been reported to increase to approximately 8 million tons in 2006 (Shurson, 2006). It has moderate protein content (~ 30% crude protein) without the presence of anti-nutritional factors commonly found in most plant protein sources. Results of earlier studies have shown that based on growth performance and feed utilization efficiency, DDGS is a promising feed ingredient for several fish species, including rainbow trout (Cheng and Hardy, 2004), tilapia (Wu et al., 1996), and channel catfish (Lovell, 1980; Tidwell et al., 1990; Webster et al., 1991; 1992; 1993).

At least four species of *ictalurid* catfish have been considered as candidates for commercial aquaculture in the USA. Channel catfish *Ictalurus punctatus* and blue catfish *I. furcatus* are the most popular two species for aquaculture (Tucker and Robinson, 1990; Dunham et al., 1993). Compared with blue catfish, the channel catfish has faster growth-to-market size, better tolerance for low oxygen, and superior resistance to some diseases (such as columnaris). However, blue catfish has superior resistance to certain diseases (such as enteric septicemia of catfish), better carcass traits, and easier harvest ability (Dunham and Argue, 2000). Research on hybrids, female channel catfish *I. punctatus* × male blue catfish *I. furcatus* (C×B), has demonstrated that they exhibit many commercially desirable characteristics. Compared to most commercially cultured strains of channel catfish, the C×B hybrid exhibits superior characteristics for the following traits: faster growth, tolerance of low oxygen, increased resistance to many diseases, tolerance to crowded growth conditions in ponds, uniformity in size and shape, higher dress out percentages, increased harvest ability by seining, and increased vulnerability to angling (Wolters et al., 1996; Masser and Dunham, 1998). The published data on the nutrition of C×B hybrid was limited. It is demonstrated that the growth and feed conversion ratio (FCR) were better for C×B hybrid fed the 25% protein diet compared to those fed the 45% protein diet (Bosworth et al., 1998). The objective of this study is to investigate the growth response and feed utilization of juvenile C×B hybrid catfish fed diets containing high level of DDGS as a replacement of a combination of SBM and corn meal (CM).

3. MATERIALS AND METHODS

3.1. DIET PREPARATION

Because lack of the basic data of nutrient requirements for hybrid catfish (C × B), a practical diet formula for channel catfish *I. punctatus* was used as the basal (control) diet in present study. Five isonitrogenous experimental diets were formulated to contain 32% protein and 6% lipid. The upper limit to DDGS was set at

30% due to processing consideration and possible degradation of pellet quality when using higher inclusion levels. The diets consisted of a basal (control) diet and diets containing 20% and 30% DDGS, with and without the addition of lysine, as partial replacements of a mixture of SBM and CM on an equal protein basis (Table 1). The list of these diets was as follows: Diet-1 (basal diet; no DDGS and no lysine supplementation), Diet-2 (20% DDGS and 0% lysine supplementation), Die-3 (20% DDGS and 0.10% lysine supplementation), Diet-4 (30% DDGS and 0% lysine supplementation) and Diet-5 (30% DDGS and 0.20% lysine supplementation). Fish oil was added to keep lipid constant in all treatments. Diets were extruded into floating pellets by Zeigler Brothers Inc. (Gardners PA, USA). The proximate composition and amino acids composition of the diets were analyzed following AOAC (1995) procedures by the New Jersey Feed Laboratory, Inc and are presented in Table 1and 2, respectively.

3.2. ANIMAL REARING

Juvenile C×B hybrids were obtained from a mix of spawning. Prior to the start of the feeding trial, fish were acclimated to the experimental conditions and fed the basal diet for 3 weeks in an indoor re-circulated water system. Fish with an average weight of 1.16-1.25 g were randomly stocked into twenty-five 75 l glass aquaria at a density of 30 fish per aquarium. Aquaria were supplied with flow-through dechlorinated tap water with continuous aeration to maintain the dissolved oxygen level above saturation. Fish in quintuplicate aquaria were randomly assigned to each of the five experimental diets and were restricted-fed at a rate equaling 5-10% of wet body weight twice daily (between 07:00-08:00 h and 14:00–15:00 h) for 8 weeks. Fish in each aquarium were group weighed and counted every two weeks. During the feeding trial, water temperature was maintained at 24-29 ^{o}C, salinity less than 5, pH 7.2-8.5. Dissolved oxygen was not less than 5 mg/l, and there were negligible levels of free ammonia and nitrite.

3.3. CALCULATIONS AND STATISTICAL ANALYSIS

At the termination of the 8-week feeding trial, fish in each glass aquarium were weighed (each replicate was group weighted) and counted.

Growth and feed utilization were expressed as follows:

Weight gain (WG, %) = 100 × (final weight – initial weight) / initial weight

Feed conversion ratio (FCR) = feed offered (g) / weight gain (g)

Protein efficiency ratio (PER) = weight gain (g) / protein offered (g)

The Statistical Analysis System (V8.01 SAS Inst. Inc., Cary, NC, USA) was used for all statistical evaluations. All data were analyzed using one-way analysis of variance (ANOVA), followed by the Duncan test. The level of significance was set at $P<0.05$.

4. RESULTS

The proximate analyses of amino acids compositions of experimental diets were confirmed by an analysis and are presented in table 2. Lysine levels ranged from 1.58% to 1.81% of the diet (dry weight basis), and methionine ranged from 0.58% to 0.62%.

At the conclusion of the eight week growth trial, survival ranged from 97.3% to 100.0% had no significant differences among the dietary treatments (Table 6). Compared with those in Diet-1 (control) and Diet-2 (20% DDGS, 0% lysine supplementation), hybrids fed Diet-4 and Diet-5 with 30% DDGS regardless of lysine supplementation had the significant higher final body weight (8.39 g and 8.67 g, respectively). Although there were no significant differences in WG among Diet-3 (20% DDGS, 0.10% lysine supplementation), Diet-4 and Diet-5, they were all significant higher than those in Diet-1. Furthermore, the highest value of WG (643.2%) was found in Diet-5.

Table 6. Growth performance and feed utilization of juvenile hybrid catfish (Ictalurus punctatus × I. furcatus) fed on experimental diets.

Item	Experimental diets					[1]PSE	P value
	Diet-1	Diet-2	Diet-3	Diet-4	Diet-5		
Survival (%)	100	100	98	97	98	0.42	0.174
Initial weight(g)	1.25	1.17	1.18	1.16	1.17	0.02	0.600
Final weight(g)	7.42[a]	7.54[ab]	8.21[bc]	8.39[c]	8.67[c]	0.14	0.006
[2]WG (%)	501[a]	547[ab]	598[b]	624[b]	643[b]	16.34	0.021
[3]FCR	2.07[c]	1.97[bc]	1.78[ab]	1.73[a]	1.74[a]	0.04	0.009
[4]PER	1.40[a]	1.49[ab]	1.62[bc]	1.66[bc]	1.69[c]	0.03	0.007

[1]PSE = Pooled Standard Error of Mean
[2]WG: Weight gain = 100 × (final weight – initial weight) / initial weight
[3]FCR: Feed conversion ratio = feed offered (g) / weight gain (g)
[4]PER: Protein efficiency ratio = weight gain (g) / protein offered (g)

There were no significant differences in FCR between Diet-4 and Diet-5 regardless of lysine supplementation. However, both had significant lower FCR than Diet-1 and Diet-2. Furthermore, the lowest FCR (1.73) was found in Diet-4 with 30% DDGS and 0% lysine supplementation. Regardless of lysine supplementation, 30% DDGS in diet leaded to significant higher PER than control. The highest value (1.69) of PER was found in Diet-5 with 30% DDGS and 0.20% lysine supplementation.

5. DISCUSSION

All treatment groups have a growth rate higher than 500% within the eight week rearing period. This is an acceptable result for controlled laboratory conditions according to the Reference of Fingerling catfish Health and Production Practices in the United States (USDA, 2003).

Most of the published data about hybrid catfish *I. punctatus* × *I. furcatus* (C × B) focus on spawning, reproduction and disease resistance (e.g., Wolters et al., 1996; Dunham and Argue, 2000; Phelps et al., 2007). Limited information on nutrition of this hybrid is available. Bosworth et al. (1998) fed diets containing 25% and 45% protein to C × B hybrid for 10 weeks and found that hybrids fed the lower protein diet had better growth and feed efficiency than those fed the high protein diet. Because lack of the basic data of nutrient requirements for C × B hybrid, in present study, a practical diet for channel catfish *I. punctatus* was used as the basal (control) diet. It is interesting, in present study, that diet of DDGS up to 30% in diet as a replacement of a combination of SBM and CM regardless of lysine addition improved the growth of C × B hybrids. This is in general agreement with previous studies, which showed that up to 30-35% DDGS could be used to partially replace SBM in channel catfish diets (Webster et al., 1991; 1992; 1993; Robinson and Li, 2008). Furthermore, in present study, the control diet with 32% soybean meal and 20% corn meal had the poorest growth. The WG in this treatment was significantly lower than those in Diet-3, Diet-4 and Diet-5 with DDGS supplementation (Table 6). Concentrations of lysine (1.58-1.81%) and methionine (0.58-0.62%) in these five experimental diets (Table 2) met the requirements of channel catfish (lysine, ~1.5%, Robinson et al., 1980; methionine,

~0.56%, Harding et al., 1977). The results implied that lysine and methionine were not the limiting amino acids in diets containing DDGS used for C × B catfish.

The lowest FCR in the current study was found in Diet-4 with 30% DDGS and no lysine supplementation. At the same time, Diet-4 had the highest PER statistically the same as Diet-5 with 30% DDGS and 0.20% lysine supplementation. It appears that replacement of dietary SBM and CM with DDGS at an up to 30% level improved the SBM and CM control diet. These results are in general agreement with the results in research of channel catfish (Robinson and Li, 2008). In that experiment, FCR was significantly lower for fish fed the SBM + DDGS diet compared to those fed a SBM control diet. However, this has not been seen in previous studies (Webster et al., 1991; 1992; 1993; Robinson and Li, 2005). Robinson and Li (Robison & Li, 2008) ascribed this difference to the underestimation of digestible energy for DDGS. Meanwhile, poor palatability of the high SBM (73.75%) supplemented diet could be another reason (Bosworth et al., 1998). At this time, in present study, we are unable to determine the reason for increases of PER and decreases of FCR caused by DDGS in C ×B hybrid diets. Ingledew (1999) estimated that 3.9% of the total biomass of DDGS was yeast, with 5.3% of the protein content of DDGS being contributed by yeast protein. Yeasts are rich in protein, B-complex vitamins and β-glucans. Therefore, fermentation could increase the digestibility of plant dietary protein sources. Comparative studies on the digestibility of some dietary protein sources, such as DDGS, SBM, CM and CSM, are needed to improve the feed formula for C ×B hybrid.

In conclusion, combination with SBM and CM, DDGS appears to be a suitable ingredient for use in C×B hybrids diets at least at levels up to 30% without lysine supplementation. This is supported by experiments with tilapia. Viola and Arieli (1983) and Teshima and Kanazawa (1988) both reported that supplementing tilapia diets with crystalline EAA did not improve fish performance. It is suggested that future research should evaluate the nutritional influence of higher levels of inclusion in combination with processing studies to evaluate the potential negative effects of DDGS on pellet stability.

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IV. SUMMARY AND CONCLUSIONS

Aquaculture has become a very important industry around world. Its contribution to global supplies of fish, crustaceans and molluscs increased from 3.9% of total production by weight in 1970 to over 50% in present (FAO. 2006). It is remarkable that half of fish consumed in the world is now farm raised. Catfish farming has grown rapidly over the last 50 years. The expansion of aquaculture production has been accompanied by rapid growth of feed production. Presently, the commercial ration of catfish is largely based on SBM and CM. Under the influence of the expansion of biofuel industry, the prices of the common feed ingredients such as soybean and corn have gone up rapidly. A cheaper protein source to replace soybean meal and corn meal becomes more desirable. Reducing feed costs without influent fish optimal fish growth goes up to the top of concern list.

Distiller's dried grains with solubles (DDGS) is one of the alternatives to replace SBM and CM. Distiller's dried grains with solubles (DDGS) is less expensive than SBM on a per unit protein basis, but its use in fish feed is limited due to its low content of essential amino acids, especially lysine (NRC 1993). The cost of feed can be further reduced if lysine supplementation can be omitted from the formulation. So the purpose of our study was set as to evaluate the effect of the dietary levels of DDGS with and without lysine supplementation on growth, feed intake, and feed efficiency of catfish. The reported research evaluated DDGS substitution in commercial catfish rations under pond productions as well as controlled aquaria studies.

Under our conditions, results from pond studies indicated that 30% DDGS containing feed without lysine supplementation can be used in channel catfish production in pond condition.

Although channel catfish is the most important species in catfish industry, researches on hybrids, female channel catfish *I. punctatus* × male blue catfish *I. furcatus* (C×B), have demonstrated that they exhibit many commercially desirable characteristics. Hybrid catfish has become a more and more important strain that is gaining commercial acceptance. However, little information is available on the nutrition requirement of this hybrid catfish. In order to confirm the results from previous study on channel catfish as well as to test certain DDGS level in hybrid catfish growth trial, a study of hybrid catfish growth trial using DDGS with and without lysine supplementation in aquaria was conducted.

The results from hybrid catfish study (table 6) showed that there were some significant differences among all treatments which are final weight, weight gain, FCR and protein efficiency ratio. This study indicates that diets without lysine supplementation containing 30% DDGS in combination with SBM and CM provide good growth and feed utilization in juvenile C × B hybrid catfish. Based on our results from both studies, a DDGS level up to 30% without lysine supplementation can be used in channel catfish and hybrid catfish diets. Further research may focus on challenging higher percentage of DDGS in catfish feed. The percentage of DDGS can be recommended as 30% and 40% with and without lysine supplementation.

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