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Research Article

# Fermented Soybean Meal as a Protein Source in Diets for Yellow Perch (*Perca flavescens*)

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**Abstract:** A feeding trial was performed to investigate fermented soybean meal as a direct fishmeal replacement in juvenile Yellow Perch *Perca flavescens* diets. Four fishmeal replacement levels (25, 50, 75 and 100%) using fermented soybean meal were compared with a fishmeal control diet. Survival, weight gain, food conversion, protein efficiency, viscerosomatic index, hepatosomatic index, Fulton-type condition, and muscle ratio were determined after 105 days. No mortalities were observed during the feeding trial. Weight gain and feed conversion ratio were significantly impacted and negatively correlated with increasing fermented soybean meal inclusion. Fish fed diets containing 75% or greater fermented soybean meal failed to reach 100% weight gain by conclusion of the trial. Hepatosomatic index and viscerosomatic index showed no impact by replacement of fishmeal. Fermented soybean meal as a direct replacement for fishmeal does not appear to be a suitable replacement.

**Keywords:** Yellow Perch; Fish Meal; Fermented soybean meal

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## Introduction

Aquaculture of Yellow Perch *Perca flavescens* increased in response to a decline in the commercial supply provided by the Great Lakes (Brown et al., 1996; Kasper, 2007). Much of the interest in Yellow Perch has focused on intensive culture, such as heavily stocked ponds or raceways and indoor culture systems (Kasper et al., 2007). Species-specific diets have been formulated to achieve maximum growth by meeting species/age nutritional requirements; however, the nutritional requirements for Yellow Perch are not yet completely known. Recommended diets for Yellow Perch culture have been those that meet the nutritional requirements for Rainbow Trout *Oncorhynchus mykiss* (Brown et al., 1996). Rainbow Trout diets generally contain high levels of fish meal (FM) as the primary protein source and are generally expensive due to the cost of FM. Determining the utilization of alternative proteins, such as plant feedstuffs, by Yellow Perch may provide lower cost diets and further decrease dependence on FM.

Numerous soybean feedstuffs have been evaluated and are available for aquaculture and are considered an important source of crude protein and essential amino acids (EAA) (Brown et al., 2008). Toasted soybean meal (SBM) (~44% to ~49% CP) is the most commonly used soy product in aquaculture diets (Brown et al., 2008) because of its moderately high protein content and EAA balance (Carter & Hauler, 2000). One drawback to use of soybean products is the presence of anti-nutritional factors (ANF) such as trypsin inhibitors and lectins; however processing of soybeans into SBM can decrease ANF concentrations (Brown et al., 2008). Fermentation of soybeans incorporates the use of microorganisms to increase nutritional value while also decreasing the ANF's (Lim and Lee 2011). As a result, FSBM has a similar EAA concentration to SBM but higher crude protein (~55%) **(Table 1)**.

Although SBM has been the most commonly tested soybean feed stuff several studies have evaluated FSBM in aquaculture diets for a variety of species including Pompano *Trachinotus ovatus* (Lin et al., 2013), Black Sea Bream *Acanthopagrus schegelii* (Zhou et al., 2011; Azarm & Lee, 2014), Japanese Flounder *Paralichthys olivaceus* (Kader et al., 2011), Rainbow Trout (Barnes et al., 2012, 2013, 2014; Bruce et al., 2017; Voorhees et al., 2019), and hybrid Striped Bass (White Bass *Morone chrysops* × Striped Bass *M. saxatilis*) (Rombenso et al., 2013). Few studies were found that tested soybean feed stuffs in Yellow Perch diets, no known studies have evaluated FSBM in Yellow Perch diets.

(Kasper et al., 2007) tested two different SBM products (solvent-extracted, dehulled SBM and expelled-extruded SBM) in Yellow Perch diets. The authors noted that Yellow Perch are able to utilize either form as a partial replacement for FM. (Schaeffer et al., 2011) noted some success in replacing FM with a combination distillers dried grains with solubles (DDGS) and SBM in Yellow Perch. Their diets containing 40% DDGS+9.5% SBM produced greater weight gains than fish fed a control diet (24% FM+31.5% SBM). (Von Eschen et al., 2019) tested soy protein concentrate (SPC) in combination with distillers dried grains with solubles (DDGS) and noted that diets containing equal parts SPC+DDGS produced the most favorable growth performance in Yellow Perch when supplemented with EAA. The objective of this research was to evaluate the effects of graded partial and total substitution of FM with FSBM on fish performance and responses when fed to juvenile Yellow Perch.

## Materials and Methods

### Experimental diets

Four experimental diets were formulated to test increasing amounts of FSBM as a direct FM replacer **(Table 2)** and were compared to a FM control diet. Direct replacement levels for FM with FSBM were 0, 25, 50, 75, and 100%. Diets were formulated to contain crude protein 44.4-56.3 ± 2.0% (mean ± SE) and gross energy (GE) 14.3-18.3 ± 0.70 MJ/kg **(Table 2)**. Gross energy values were estimated using 4.11, 5.64, and 9.44 kcal/g for carbohydrates, proteins, and lipids, respectively, multiplied by the composition values for each ingredient (**Table 2**; NRC 2011).

Feed were processed using a pilot-scale Wenger TX-52 twin-screw extruder (Wenger Inc., Kansas City, MO). Feeds were extruded into 2 mm diameter pellets, dried at room temperature, crumbled to appropriate size, and stored at -20ºC. Dried pellets were analyzed for crude protein (AOAC 2006, Method 990.03), crude fat (AOAC 2006, Method 990.03), crude fiber (AOAC, 2006; Method 978.10), moisture (AOAC, 2006; Method 934.01) and ash (AOAC, 2006; Method 942.05).

### Fish and culture system

Age-0 Yellow Perch were held in a 340 L flow-through tank and feed trained to accept a commercial pelleted diet (BioDiet Grower, Bio-Oregon, Warrenton, OR). Following the feed training interval, 14 fish (initial mean weight=26.2 ± 3.05 g) were randomly selected and stocked into each of 24, 110-L circular tanks, providing five replicates per treatment and four replicates for the control diet.

The feeding trial was performed in a closed loop recirculation

**Table 1:** EAA concentrations (g/100 g, db) of soybean feedstuffs and fish meal.

| | Proteins | | Estimated | |
|---|---|---|---|---|
| EAA[a] | FSBM[b] | SBM[c] | FM[bd] | Requirement[e] |
| Arginine | 3.6 | 3.9 | 6.3 | 2 |
| Histidine | 1.4 | 1.4 | 2.3 | 0.9 |
| Isoluecine | 2.6 | 2.4 | 4.4 | 1.4 |
| Leucine | 4.3 | 4.2 | 7.2 | 2.3 |
| Lysine | 3.1 | 3.3 | 7.7 | 2.6 |
| Methionine | 0.8 | 0.7 | 2.9 | 0.8 |
| Phenylalanine | 2.7 | 2.6 | 3.8 | 1.4 |
| Theronine | 2.1 | 2.1 | 4 | 1.4 |
| Tryptophan | 0.8 | 0.8 | 1.1 | 0.3 |
| Valine | 2.8 | 2.5 | 6 | 1.6 |

[a]Essential amino acids
[b]Nutraferma, North Sioux City, SD, USA
[c]Brown (2008)
[d]Menhaden fish meal, Omega Protein, Inc., Houston, TX, USA
[e] Source: Hart et al. (2010)

**Table 2:** Composition (g/100 g, db) and proximate composition analysis (%) of experimental diets containing various levels of fermented soybean meal (FSBM).

| | Diets (FM % /FSBM %) | | | | |
|---|---|---|---|---|---|
| Ingredients | 100/0 | 75/25 | 50/50 | 25/75 | 0/100 |
| Herring Fish Meal[a] | 42.96 | 32.22 | 21.48 | 10.74 | 0 |
| FSBM[b] | 0 | 11.36 | 22.73 | 34.09 | 45.45 |
| Celufil[c] | 10.6 | 9.9 | 9.1 | 8.4 | 7.6 |
| Lasi Trout Mix (min/vit)[d] | 3.11 | 3.11 | 3.11 | 3.11 | 3.11 |
| Rovimix Stay-C 35[e] | 0.53 | 0.53 | 0.53 | 0.53 | 0.53 |
| Wheat flour (whole)[f] | 15.96 | 15.96 | 15.96 | 15.96 | 15.96 |
| Corn gluten meal[g] | 27.41 | 27.41 | 27.41 | 27.41 | 27.41 |
| Menhaden oil[h] | 5.9 | 6.6 | 7.4 | 8.1 | 8.9 |
| Proximate Composition[i] (%) | | | | | |
| Crude Protein | 56.34 | 49.23 | 48.23 | 46.65 | 44.47 |
| Crude Lipid | 12.69 | 10.86 | 9.75 | 9.93 | 9.6 |
| Crude Fiber | 8.8 | 6.84 | 6.3 | 6.77 | 9.62 |
| Gross Energy (GE) | 18.31 | 15.91 | 15.23 | 14.93 | 14.29 |

[a]Lortscher Agri Service, Inc., Bern, KS, USA.
[b]Nutraferma, North Sioux City, SD, USA.
[c]USB Corporation, Cleveland, OH, USA.
[d]Lasi Fish Premix, NB-8055, Lortscher Agri Service, Inc., Bern, KS, USA.
[e]DSM Nutritional Products France SAS, Village-Neuf, France.
[f]Bob's Red Mill Natural Foods, Inc., Milwaukie, OR, USA.
[g]Consumers Supply Distributing Company, Sioux City, IA, USA.
[h]Omega Protein, Inc., Houston, TX, USA.
[i]Analyses conducted on dried post-extrusion feed pellets.

system consisting of a solids separation tank, bio-reactor, and 100 µm bag, charcoal and UV irradiation filtration. Water exchange rates were 25 exchanges per 24 h period. Water temperature was held constant at 23°C with an 1800W single-phase bayonet heater (Process Technology, Mentor, OH). Tanks were cleaned daily of feces and uneaten feed with a siphon. Nitrite (Hach, 2008; method 8153), nitrate (Hach, 2008; method 8039), and total and free ammonia (Hach, 2008; method 8038) nitrogens were monitored weekly using a Hach DREL 2000 spectrophotometer (Hach Company, Loveland, CO). Water pH was tested weekly using an Oakton multi-parameter PCS Testr 35 (Eutech Instruments, Vernon Hills, Illinois). Dissolved oxygen (DO) was measured twice per week using a YSI Model 55 DO meter (Yellow Springs Instrument Corp., Yellow Springs, OH). Water pH remained stable at 7.8-8.2 throughout the duration of the feeding trial. Un-ionized ammonia ranged from 0.00-0.04 mg/L. Nitrate-nitrogen ranged from 1.0-4.0 mg/L. Nitrite-nitrogen ranged from 0.01-0.36 mg/L. Un-ionized free ammonia was calculated from total ammonia nitrogen and ranged from 0.000-0.040 mg/L. The DO ranged from 6.4-7.4 mg/L. Photoperiod was maintained at 15 h light: 9 h dark for the duration of the feeding trial.

Fish were hand-fed set rations of 2 to 3% of tank biomass, split into two feedings per day. Consumption was monitored to ensure fish were not under fed. Total tank biomass was measured every 21 days and feed rations were adjusted according to tank biomass and observed consumption. Upon completion of the feeding trial, total tank weights were measured as well as individual lengths and weights.

Whole body, liver, visceral, and fillet weights were measured to determine organosomatic indices, condition, and muscle ratio (MR). Muscle tissues were collected for proximate analysis, amino acid profiles, and color differences. Livers were collected for fatty acid profiles, organosomatic indices, and color differences from euthanized fish.

**Fish analyses**

Performance indices were used to determine responses to treatment diets. Percent weight gain was calculated as WG=100×(final weight (g)-initial weight (g))/initial weight (g)) (NRC, 2011). Feed conversion ratio was calculated as FCR=(weight of diet fed (g)/total wet weight gain (g)) (NRC 2011). Protein efficiency ratio was calculated as PER=(weight gain (g)/protein fed (g)) (NRC, 2011). Consumption was estimated as the total feed fed minus feed remaining during the feeding trial.

General health and condition indicies were determined from necropsy data including: viscerosomatic index [VSI=(visceral weight (g)/body weight (g))×100], hepatosomatic index [HSI=(liver weight (g)/body weight (g))×100], and muscle ratio [MR=((fillet weight (g)×2)/body weight (g))×100] (NRC, 2011). Fulton-type condition factor was calculated [$K$=(W(g)/L(cm)$^3$)×100,000] using individual lengths and weights.

Proximate analysis was determined on the fillets including crude protein (AOAC, 2006; Method 990.03), crude fat (AOAC, 2006; Method 990.03), crude fiber (AOAC, 2006; Method 978.10), moisture (AOAC, 2006; Method 934.01) and ash (AOAC, 2006; Method 942.05). Amino acid profiles were completed on individual fillets (AOAC, 2006; Method 982.30 E(a,b,c)).

**Statistical analysis**

All response variables were analyzed using analysis of variance (ANOVA). Significant ANOVA results ($p \leq 0.05$) were further analyzed with Turkey's range tests to determine mean differences (Steele et al., 1997). Systat (version 11) software (SPSS Inc. Chicago, Illinois) and Microsoft Excel (Microsoft, Redmond, Washington) were used to perform all statistical analyses.

# Results

No mortalities were observed during the feeding trial and all fish fed actively on prepared diets. Consumption was not impacted by diet composition ($F$=2.8, df 4, 19, $p$<0.06), the only difference observed was between the control diet and the diet containing 100% FSBM as a protein source. Analyses of the diets indicated that only the control diet fully met all essential amino acid requirements suggested for Yellow Perch by (Hart et al., 2010) **(Table 3)**. As FSBM increased in the diets, a decrease in crude protein was observed **(Table 3)**. Diets containing FSBM met all essential amino acid requirements with the exception of lysine. All EAA (arg, his, iso, leu, lys, met, phe, the, try, and val) levels decreased as substitution of fish meal increased, with the exception of tryptophan **(Table 3)**. Analysis of the resulting muscle tissue determined that only methionine ($F$=5.1, df 2,9,

**Table 3:** Amino acid composition (g/100 g db) of the experimental diets fed to juvenile Yellow Perch in this study.

| | Diets (FM%/FSBM%) | | | | | Estimated |
|---|---|---|---|---|---|---|
| Amino Acid[a] | 100/0 | 75/25 | 50/50 | 25/75 | 0/100 | requirement[b] |
| Arginine | 2.70 | 2.32 | 2.29 | 2.22 | 2.19 | 2.0 |
| Histidine | 1.21 | 1.09 | 1.06 | 1.03 | 1.01 | 0.9 |
| Isoluecine | 2.23 | 2.02 | 1.99 | 1.95 | 1.90 | 1.4 |
| Leucine | 5.91 | 5.16 | 5.04 | 4.87 | 4.77 | 2.3 |
| Lysine | 3.08 | 2.41 | 2.20 | 1.99 | 1.77 | 2.6 |
| Methionine | 1.44 | 1.11 | 1.02 | 0.90 | 0.82 | 0.8 |
| Phenylalanine | 2.64 | 2.37 | 2.36 | 2.34 | 2.32 | 1.4 |
| Theronine | 2.03 | 1.71 | 1.66 | 1.54 | 1.52 | 1.4 |
| Tryptophan | 0.48 | 0.45 | 0.47 | 0.49 | 0.48 | 0.3 |
| Valine | 2.74 | 2.41 | 2.33 | 2.26 | 2.14 | 1.6 |

[a]Essential amino acids.
[b]Source: Hart et al. (2010).

$p$=0.03), and histidine ($F$=19.7, df 2, 9, $p$<0.01) were significantly different among dietary treatments **(Table 4)**.

Weight gain was significantly impacted by diet composition ($F$=31.3, df 4, 19, $p$<0.01) **(Table 5)** and showed a negative correlation with increasing FSBM (r=-0.92, $p$<0.01). Declines in weight gain were observed as FSBM inclusion increased, greatest mean weight gain was observed in fish fed the control diet. Diets containing ≥ 75% FSBM failed to produce 100% weight gain by the end of the trial.

Diet composition had a significant impact on FCR ($F$=16.4, df 4, 19, $p$<0.01) and negative correlation with increasing FSBM (r=-0.84, $p$<0.01) **(Table 5)**. Significant differences were also observed in PER ($F$=5.2, df 4, 19, $p$<0.01), however, no correlation with FSBM level was detected (**Table 5**). HSI was not significantly different among diets ($F$=1.9, df 4, 19, $p$=0.16) **(Table 5)**. The MR also significantly differed among diet treatments ($F$=3.0, df 4, 19, $p$=0.04), but was uncorrelated with FSBM levels **(Table 5)**. Significant differences were observed for $K$ values ($F$=3.0, df 4, 19, $p$=0.04) **(Table 5)**. Diets containing 75% FSBM had lower $K$

**Table 4:** EAA and proximate composition (g/100 g db) of juvenile Yellow Perch fillets. Values not significantly different (p>0.05) have the same letter within a given column.

| | Diet (FM %/FSBM %) | | |
|---|---|---|---|
| EAA | 100/0 | 50/50 | 0/100 |
| Arginine | 5.18 ± 0.02 z | 5.25 ± 0.03 z | 5.11 ± 0.03 z |
| Histidine | 2.42 ± 0.02 z | 2.55 ± 0.01 y | 2.55 ± 0.02 y |
| Isoleucine | 4.20 ± 0.05 z | 4.29 ± 0.03 z | 4.19 ± 0.03 z |
| Leucine | 7.06 ± 0.02 z | 7.15 ± 0.03 z | 6.97 ± 0.03 z |
| Lysine | 8.04 ± 0.03 z | 7.96 ± 0.03 z | 7.92 ± 0.04 z |
| Methionine | 2.68 ± 0.01 z | 2.73 ± 0.01 y | 2.68 ± 0.02 z |
| Phenylalanine | 3.78 ± 0.01 z | 3.77 ± 0.02 z | 3.74 ± 0.02 z |
| Threonine | 3.69 ± 0.03 z | 3.69 ± 0.03 z | 3.62 ± 0.05 z |
| Tryptophan | 1.07 ± 0.02 z | 1.11 ± 0.01 z | 1.07 ± 0.01 z |
| Valine | 4.51 ± 0.04 z | 4.58 ± 0.03 z | 4.44 ± 0.03 z |
| Proximate Composition (%) | | | |
| Crude Protein | 93.4 | 92.02 | 91.43 |
| Crude Fat | 3.83 | 4.77 | 5.27 |
| Crude Fiber | 0.16 | 0.06 | 0.07 |
| Ash | 8.74 | 8.46 | 8.09 |

**Table 5:** Mean weight gain (WG), food conversion ratio (FCR), protein efficiency ratio (PER), viscerosomatic index (VSI), hepatosomatic index (HSI), Fulton-type condition factor (K), muscle ratio (MR) of experimental diets containing varying levels of fish meal (FM) and fermented soybean meal (FSBM). Values are treatment means (± SE) for experimental diets. Values not significantly different (p>0.05) have the same letter within a given column.

| FM%/FSBM% | WG (%) | FCR | PER | VSI (%) | HSI (%) | K | MR (%) |
|---|---|---|---|---|---|---|---|
| 100/0 | 141.1 ± 7.2 z | 1.9 ± 0.08 z | 1.01 ± 0.05 yz | 9.48 ± 0.29 z | 1.66 ± 0.27 z | 1.27 ± 0.02 z | 41.3 ± 0.4 yz |
| 75/25 | 119.0 ± 3.4 y | 2.1 ± 0.04 yz | 1.12 ± 0.02 yz | 9.03 ± 0.08 z | 1.26 ± 0.07 z | 1.23 ± 0.03 yz | 41.8 ± 0.3 z |
| 50/50 | 110.9 ± 3.8 xy | 2.2 ± 0.06 xyz | 1.11 ± 0.03 xyz | 8.80 ± 0.20 z | 1.29 ± 0.12 z | 1.22 ± 0.03 yz | 40.3 ± 0.7 yz |
| 25/75 | 97.5 ± 1.3 x | 2.3 ± 0.03 wxy | 1.05 ± 0.01 xyz | 9.73 ± 0.41 z | 1.34 ± 0.06 z | 1.09 ± 0.12 y | 38.8 ± 0.8 y |
| 0/100 | 73.0 ± 5.4w | 2.8 ± 0.16 w | 0.92 ± 0.06 z | 9.80 ± 0.23 z | 1.17 ± 0.09 z | 1.11 ± 0.11 yz | 39.6 ± 1.0 yz |

**Table 6:** Hunter color levels of resulting fillets associated with various levels of FSBM fed to juvenile Yellow Perch in this study.

| | Diets (FM%/FSBM%) | | | | |
|---|---|---|---|---|---|
| Color | 100/0 | 75/25 | 50/50 | 25/75 | 0/100 |
| Hunter L | 39.84 z | 35.23 y | 41.21 z | 37.65 z | 37.82 z |
| Hunter a | -1.40 z | -0.88 z | -1.51 z | -1.32 z | -1.40 z |
| Hunter b | 6.22 z | 5.37 z | 6.09 z | 5.08 z | 5.59 z |

**Table 7:** Hunter color levels of resulting livers associated with various levels of FSBM fed to juvenile Yellow Perch in this study.

| | Diets (FM%/FSBM%) | | | | |
|---|---|---|---|---|---|
| Color | 100/0 | 75/25 | 50/50 | 25/75 | 0/100 |
| Hunter L | 1.05 z | 0.96 z | 1.09 z | 0.96 z | 1.08 z |
| Hunter a | 1.16 z | 1.07 z | 1.03 z | 1.02 z | 0.93 z |
| Hunter b | 0.69 z | 0.62 z | 0.69 z | 0.59 z | 0.68 z |

values than the diet containing 100% FSBM; however, both were lower than the other three diets. No significant differences were observed in VSI values ($F$=2.7, df 4, 19, $p$=0.07).

Analyses of Hunter color *L, a,* and *b* values for fillets revealed a significant difference in the *L* value ($F$=3.73, df 4, 115, $p$<0.01), but no differences in *a,* or *b* values ($F$=1.62, df 4, 115, $p$=0.18) and ($F$=1.89, df 4, 115, $p$=0.12), respectively. No relationships were observed in fillet color values with increasing FSBM **(Table 6)**. Hunter color analyses of fish livers revealed no significant differences in color *L, a,* or *b* with inclusion level of FSBM; however, a negative correlation was observed in liver Hunter *a* (r=-0.49, $p$=0.21) as livers decreased in redness with increasing FSBM **(Table 7)**.

## Discussion and Conclusion

All fish fed actively on each diet formulation and showed no signs of nutritional deficiency. Although depressed growth was observed as FSBM increased, zero mortalities were observed during the study. Similarly Von Eschen et al. (2019) noted zero mortalities in Yellow Perch fed combinations of SPC+DDGS with and without EAA supplementation. Kasper et al. (2007) noted the form of SBM offered and the concentration in the diet significantly influenced Yellow Perch survival. (Schaeffer et al., 2011) observed nearly 100% survival (two mortalities) when feeding combinations of DDGS + SBM to Yellow Perch. (Zhou et al., 2011) observed no significant effect on survival of Black Sea Bream fed diets including varying amounts of FSBM. Likewise, (Azarm & Lee 2014) found no significant difference in survival with FSBM inclusion in diets fed to Black Sea Bream. (Kader et al., 2011) noted survival was not significantly impacted in Japanese Flounder fed diets containing FSBM.

Diet composition produced significant differences in weight gain and was negatively correlated with FSBM levels **(Table 3)**. The diet containing 100% FSBM produced the lowest weight gain, suggesting that 100% replacement of FM with FSBM would not be satisfactory for intensive Yellow Perch aquaculture. Lin et al. (2013) observed decreases in growth as FM was directly replaced with FSBM in experimental diets fed to Pompano. (Zhou et al., 2011) experienced similar results in that growth was depressed as FSBM increased in diets fed to Black Sea Bream. (Kader et al., 2011) also reported a similar decline in growth as FSBM increased in diets fed to Japanese Flounder. Conversely, Azarm and Lee (2014) found that final body weight or specific growth rate of Black Sea Bream was not significantly affected by FSBM level in the diets they tested. Barnes et al. (2012) found that Rainbow Trout produced greatest growth when FSBM directly replaced FM at 10 and 20%; however, at levels greater than 30% FSBM inclusion growth continually declined. Although weight gain was depressed in this study, the results indicate that Yellow Perch are able to utilize low inclusion levels of FSBM as a FM replacement.

As FM in the diets decreased, EAA also decreased **(Table 3)** and this could have had an impact on decreased performance. Lysine was the only EAA that did not meet the recommended requirement for Yellow Perch. Lysine is often the first limiting amino acid in feeds, particularly those formulated with high levels of plant proteins. Inadequate levels of lysine and methionine can lead to reduced growth and feed efficiency (NRC, 2011). Supplementing FSBM with additional lysine and methionine may result in increased growth performance. Takagi et al. (2001) found that when SPC was supplemented with methionine and lysine in diets for Red Sea Bream growth was greater than for fish fed unsupplemented diets. Similar results were observed by El-Saidy & Gaber (2002) who found improved growth in Nile Tilapia fed diets containing SBM that was supplemented with lysine. Based on those results, it appears that soybean feedstuffs require additional EAA supplements to produce desired results.

Condition factor (*K* values) was significantly different among treatment fish. Schaeffer et al. (2011) found no difference in *K* values when SBM was incorporated in diets fed to Yellow Perch at 9.5% and greater. The FCR values in this study indicated that as FSBM increased, FCR decreased. Lim & Lee (2011) found FCR increased with FSBM inclusion, and was highest when FSBM was combined with fermented cottonseed meal for Nile Tilapia diets. Yuan et al. (2013) noted a similar increase FCR when FSBM increased in the diets of Chinese Sucker *Myxocyprinus asiaticus*. Nguyen et al. (2015) noted significantly lower FCR's in Yellowtail *Seriola quinqueradiata* fed two different FSBM+FM combinations when compared to a FM control diet, however no difference was observed when FSBM+FM was supplemented with Taurine. PER values were significantly different in this study however, no relationship was observed in PER and FSBM inclusion. Yuan et al. (2013) found a decreasing trend in PER with increasing FSBM in the diets of Chinese Sucker. Schaeffer et al. (2011) found no significant differences in PER with varied amounts of DDGS plus SBM fed to Yellow Perch.

Hepatosomatic index values did not differ among the treatment fish. Liver weights in this study ranged from 1.9 to 3.0% of the bodyweight, but did not increase in size with increasing FSBM. Von Eschen et al. (2019) noted no difference in HSI in Yellow Perch when fed SPC+DDGS regardless of DDGS inclusion level and EAA supplementation. Similar results were found by (Lin et al., 2011) who noted no HSI relationship in Pompano when FM was replaced with increasing levels of FSBM. Likewise, (Rombenso et al., 2013) noted no difference in hybrid Striped Bass fed diets containing traditional SBM or FSBM. However, (Kader et al., 2011) found increasing HSI values in Japanese Flounder as FSBM and squid by-product meal increased. In this study, no difference was observed in VSI values. In a study, evaluating DDGS+SBM in Yellow Perch diets (Schaeffer et al., 2011) noted no difference in VSI values. Lin et al. (2013) found VSI values were highest when FSBM was included at 200 g/kg in diets fed to Pompano.

In this study, liver color decreased in redness as FSBM increased in the diet. A decrease in liver glycogen is generally attributed to increased lipids in the diets; however, lipid concentration decreased as FSBM increased. With the exception of Hunter *a* in the livers no other color differences or correlations were observed in the livers **(Table 6)** or in the muscle tissues **(Table 7)**.

The results from this feeding trial are similar to the findings of (Kasper et al., 2007) who found, when testing SBM as a FM replacement, that Yellow Perch fed diets containing ≥ 50% SBM experienced decreased performance. The trends from this trial and other studies (Kasper et al., 2007; Schaeffer et al., 2011), which have incorporated plant proteins in the diets of Yellow Perch, indicate that Yellow Perch performance decreases when 50% of the protein is replaced with plant proteins. Use of FSBM along with EAA supplements in Yellow Perch diets have not been tested to determine if performance is increased. Increased performance has been observed in other fishes fed plant proteins with supplemented amino acids and this would be anticipated if EAA supplements were incorporated into these Yellow Perch diets. Further testing with FSBM and EAA supplements should be considered in attempt to reduce dependence on FM while increasing performance of the FSBM. In conclusion, FSBM does not appear to be a favorable alternative when compared as a direct replacement for FM in Yellow Perch.

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