THE CENTER FOR AQUACULTURE TECHNOLOGIES

Results of a Collaborative Feeding Trial

Confluence Genetic’s Ultra-High Protein, Low Oligosaccharide Soybean Meal is a High-Quality Ingredient to Replace Soy Protein Concentrate in Atlantic Salmon Diets

confluence™ GENETICS

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INTRODUCTION

Solvent-extracted soybean meal (SBM) is an attractive protein source for fish feed because of its high protein content, favorable amino acid profile, and low cost (Booman et al., 2018). In Atlantic salmon (*Salmo salar*), SBM can be included in the diet at low levels without significant negative effects on feed intake or fish growth (Booman et al., 2018). However, a higher (>20%) inclusion rate of SBM in Atlantic salmon diets can cause a gut inflammatory response called SBM-induced enteritis, which negatively impacts growth performance (Baeverfjord and Krogdahl, 1996). This adverse response to SBM in Atlantic salmon has been linked to various anti-nutritional compounds in soybeans, including oligosaccharides (raffinose and stachyose) and saponins (Agboola et al., 2022; Krogdahl et al., 2015). These anti-nutritional compounds are removed when soybeans are processed into soy protein concentrate (SPC), which is widely used as a protein source in fish feed. Through genetic improvements Confluence Genetics has created Ultra-High Protein, Low Oligosaccharide (UHP-LO) soybean varieties and SBM that better matches SPC in terms of protein content and anti-nutrient levels, including >53% protein (as-is) and <1% oligosaccharides (as-is).

OBJECTIVES

- Assess Confluence Ultra-High Protein, Low Oligosaccharide (UHP-LO) soybean meal (SBM) as an alternative ingredient to soy protein concentrate in Atlantic salmon diets.
- Evaluate the effects of different dietary inclusion levels of UHP-LO SBM on growth performance and feed conversion ratio in Atlantic salmon.
- Determine the nutrient digestibility of UHP-LO SBM in Atlantic salmon diets.

CONCLUSIONS

- Confluence Ultra-High Protein, Low Oligosaccharide (UHP-LO) soybean meal (SBM) is a valuable ingredient to replace soy protein concentrate (SPC) in Atlantic salmon diets.
- UHP-LO SBM can be included in Atlantic salmon diets up to 30% (as-fed) while maintaining par growth performance and feed conversion ratio compared to SPC.
- Dietary inclusion of UHP-LO SBM improved or had no effect on lipid, energy, protein and essential amino acid digestibility in Atlantic salmon diets.

GROWTH TRIAL

METHODS

In the growth trial, post-smolt Atlantic salmon (initial mean body weight ± standard deviation: 241.9 ± 6.3 g) were randomly allocated into 12 400-L tanks with 35 fish/tank and fed with one of the five experimental diets (Diets 1-5). Each diet was randomly assigned to triplicate tanks, and fish were hand fed for 84 days. Five isonitrogenous (42% crude protein) and isolipid (25% crude lipid) experimental diets were formulated to meet the known essential nutrient requirements of post-smolt Atlantic salmon (NRC, 2011). The positive control diet (Diet 1) was prepared using soy protein concentrate (SPC), fishmeal, and poultry by-product meal (PBM) as the primary protein sources. An additional two diets were formulated with increasing graded levels (10% and 30%) of UHP-LO SBM to progressively replace SPC (Diet 2 and 3). The practical diet (Diet 4) was formulated to contain no PBM to mimic European salmon diets. The negative control diet (Diet 5) was prepared using conventional solvent extracted SBM. Experimental ingredients and diets were analyzed by Trouw Nutrition Laboratories in accordance with A.O.A.C. (Association of Official Analytical Chemists) official methods. The nutrient composition of UHP-LO SBM and feed formulation of the experimental diets are shown at **Table 1** and **Table 2**, respectively.

RESULTS AND DISCUSSION

The results demonstrated that inclusion of UHP-LO replacing SPC had no impact on performance. Weight gain and feed conversion ratio (FCR) were similar in fish fed the positive control diet (SPC) and the UHP-LO SBM 10% and 30% inclusion diets, suggesting that UHP-LO SBM can completely replace SPC in salmon diets. Fish groups fed the practical diet and negative control diet (conventional SBM) without poultry by product meal had lower feed intake and poorer growth compared to the other groups. Overall, salmon fed UHP-LO SBM outperformed salmon fed conventional solvent-extracted SBM, revealing the potential for UHP-LO SBM to become an important protein source in the salmon feed market. Results of the growth trial are shown in **Table 3**.

DIGESTIBILITY TRIAL

METHODS

A 56-day digestibility trial was conducted with one reference diet (25% SPC) and three test diets containing 10% to 30% of UHP-LO SBM with triplicate groups of 22 Atlantic salmon (initial mean body weight of 600 ± 11.4 g) to determine nutrient apparent digestibility coefficient (ADCs) of diets and ingredients. One reference diet (Diet 1) was formulated to meet the known nutrient requirements of Atlantic salmon (NRC, 2011) using fishmeal, soy protein concentrate (SPC), and poultry by-product meal as the main protein sources and contained 0.5% titanium dioxide (TiO2) as the inert marker. The reference diet was then blended with the UHP-LO SBM test ingredient according at the ratios of 90:10 (Diet 2), 80:20 (Diet 3) and 70:30 (Diet 4). The feed formulas for the experimental diets are presented in **Table 4**. The proximate composition and amino acid content of the test ingredients, experimental diets, and fecal samples were analyzed by the Feeds Innovation Institute of the University of Saskatchewan with the standard methods of Association of Official Analytical Chemist (AOAC). The concentration of titanium oxide in the diets and feces were measured using the methods described by Short et al. (1996) and Myers et al. (2004).

RESULTS AND DISCUSSION

When looking at the digestibility of the trial diets, the results showed that adding UHP-LO to Atlantic salmon diets in amounts ranging from 10% to 30% improved or had no impact on lipid, energy, protein, and essential amino acid apparent digestibility coefficients (ADCs). While lipid digestibility was identical between treatment diets, the ADCs of energy, protein and essential amino acids increased significantly with increasing proportion of UHP-LO SBM from 0 to 30%. Results of the nutrient digestibility of the trial diets are shown in **Table 5**.

When looking at the digestibility of the test ingredient, UHP-LO SBM was highly digestible with the average ADC values of energy, protein, and amino acids ≥ 96%, which could be primarily attributed to low concentrations of oligosaccharides (Glencross et al., 2003). The digestibility of several nutrients was greater than 100%, which is not biologically logical. Such high values were due in part to the compounding errors associated with analytical nutrient and marker measurement, non-representative samples and/or interaction between ingredients when plant protein blends were used to assess apparent ingredient digestibility (Glencross, 2020). Results of the nutrient digestibility of the UHP-LO SBM test ingredient are shown in **Table 6**.

TABLE 1:

Analyzed nutrient composition of Ultra-High Protein, Low Oligosaccharide (UHP-LO) soybean meal (SBM)

Nutrient (%, dry matter)	UHP-LO SBM
Dry matter	90.9
Crude protein	60.5
Crude lipid	1.2
Ash	6.6
Gross energy (MJ/kg)	20.0
Arginine	4.4
Histidine	1.5
Isoleucine	2.7
Leucine	4.5
Lysine	3.7
Methionine	0.8
Phenylalanine	3.0
Threonine	2.3
Tryptophan	0.8
Valine	2.8

TABLE 2:

Feed formula and nutrient composition of experimental diets

Ingredient	Diet (%, as-fed) 1 (Positive control SPC)	2 (UHP-LO SBM 10%)	3 (UHP-LO SBM 30%)	4 (Practical)	5 (Negative control SBM)
Choline chloride 60%	0.2	0.2	0.2	0.2	0.2
DL- Methionine	0.335	0.332	0.327	0.356	0.354
Fish oil herring	20.414	20.33	20.161	21.272	21.648
Fishmeal herring	15	15	15	15	15
L-Histidine	0.149	0.146	0.14	0.136	0.124
L-Lysine	1.134	1.116	1.08	1.191	1.341
Monosodium phosphate (23% P)	1.88	1.815	1.685	2.11	1.91
Poultry by-product meal (pet food)	7.731	7.581	7.28	0	0
Soybean meal (solvent-extracted)	0	0	0	0	25
UHP-LO soybean meal (solvent-extracted)	0	10	30	0	0
Soy lecithin	1	1	1	1	1
Soy protein concentrate	25	16.667	0	30	12.85
Vitamin C (Stay-C)	0.3	0.3	0.3	0.3	0.3
Vitamin and mineral premix	0.3	0.3	0.3	0.3	0.3
Wheat gluten meal	9	9	9	11.893	10.973
Wheat flour	17.557	16.214	13.527	16.242	9
Total	**100**	**100**	**100**	**100**	**100**
Analyzed proximate composition (%, as-fed)					
Dry matter	95.8	97.7	96.2	95.5	97.1
Crude protein	44.3	45.7	44.6	45.3	44.4
Crude lipid	21.6	22.2	22.5	20.6	23.8
Ash	7.7	8.3	8	7.6	8
Analyzed essential amino acid composition (%, as-fed)					
Arginine	2.47	2.51	2.87	2.43	2.52
Histidine	1.04	1.06	1.11	1.23	1.07
Isoleucine	1.84	1.76	1.82	1.8	1.82
Leucine	3.13	3.06	3.14	3.06	3.09
Lysine	3.18	3.11	3.12	2.85	3.23
Methionine	1.11	1.12	1.07	1.06	1.08
Phenylalanine	2.85	2.86	2.08	2.18	2.9
Threonine	1.56	1.58	1.58	1.43	1.56
Valine	2.14	2.05	2.06	2.01	2.04
Analyzed non-essential amino acid composition (%, as-fed)					
Aspartic acid	3.56	3.63	3.87	3.5	3.7
Alanine	1.96	1.93	1.97	1.74	1.79
Cystine	0.449	0.413	0.541	0.619	0.568
Glycine	2.07	2.07	2.16	1.94	1.79
Glutamic acid	8.85	8.98	9.03	8.98	9.06
Hydroxyproline	0.28	0.28	0.87	0.09	0.09
Proline	2.8	2.79	2.84	2.97	2.76
Serine	1.83	1.93	1.94	1.85	2.01
Taurine	0.08	0.08	0.07	0.05	0.05
Tyrosine	1.56	1.56	1.54	1.57	1.55

TABLE 3:

Initial body weight, final body weight, weight gain, feed intake, and feed conversion ratio (FCR) of post-smolt Atlantic salmon fed the experimental diets containing graded levels of Confluence Ultra-High Protein, Low Oligosaccharide (UHP-LO) soybean meal (SBM) along with control diets

Diet	Initial Body Weight (g / fish)	Final Body Weight (g / fish)	Weight Gain (g / fish)	Feed Intake (g / fish)	Feed Conversion Ratio (FCR)
1 (Positive control - SPC)	240.1 (3.0)[ab]	594.6 (25.5)[a]	354.5 (23.5)[a]	301.8 (20.1)[ab]	0.86 (0.01)[ab]
2 (UHP-LO SBM 10%)	241.8 (1.7)[ab]	557.6 (7.2)[abc]	315.9 (7.4)[abc]	264.6 (7.4)[abc]	0.84 (0.01)[a]
3 (UHP-LO SBM 30%)	238.3 (1.7)[ab]	568.5 (20.9)[abc]	330.2 (19.9)[ab]	282.4 (16.4)[ab]	0.85 (0.01)[ab]
4 (Practical)	234.6 (2.7)[b]	495.5 (9.1)[c]	261.0 (11.2)[bc]	222.5 (7.8)[c]	0.85 (0.01)[ab]
5 (Negative control - SBM)	245.1 (3.6)[ab]	504.5 (2.0)[bc]	259.5 (1.8)[c]	222.6 (4.5)[c]	0.88 (0.03)[ab]
P-value	**0.0353**	**0.001**	**0.0004**	**0.0001**	**<0.0001**

Data are means (standard errors). Means within a column with no superscript in common differ significantly (P<0.05) based on one-way ANOVA, followed by Tukey's post-hoc test.

TABLE 4:
Feed formula and nutrient composition of digestibility diets

Ingredient	Diet (%, as-fed) 1 (Reference - SPC)	2 (UHP-LO SBM 10%)	3 (UHP-LO SBM 20%)	4 (UHP-LO SBM 30%)
Choline chloride 60%	0.2	0.18	0.16	0.14
DL-Methionine	0.238	0.214	0.19	0.167
Fish oil herring	19.655	17.69	15.724	13.759
Fishmeal herring	25	22.5	20	17.5
L-Histidine	0.183	0.165	0.146	0.128
L-Lysine	1.4	1.26	1.12	0.98
Monosodium phosphate (23% P)	2.11	1.899	1.688	1.477
Poultry by-product meal (Low ash)	7	6.3	5.6	4.9
Soy lecithin	1	0.9	0.8	0.7
Soy protein concentrate	11.626	10.463	9.301	8.138
Vitamin C (Stay-C)	0.3	0.27	0.24	0.21
Vitamin and mineral premix	0.3	0.3	0.3	0.3
Wheat gluten meal	10.127	9.114	8.102	7.089
Wheat flour	20.361	18.245	16.129	14.013
UHP-LO soybean meal (solvent-extracted)	0	10	20	30
Titanium dioxide	0.5	0.5	0.5	0.5
Total	**100**	**100**	**100**	**100**
Analyzed proximate composition (%, dry matter)				
Dry matter	98.1	91.4	94	95.1
Crude protein	50	52.2	53.8	54.8
Crude lipid	18	13.3	12.1	11.3
Ash	9.2	9.2	9.2	9
Gross energy (MJ/kg)	22.7	22	21.4	22.1
Analyzed essential amino acid composition (%, dry matter)				
Arginine	2.75	3.03	3.28	3.39
Histidine	1.26	1.37	1.39	1.4
Isoleucine	2.08	2.26	2.31	2.52
Leucine	3.47	3.77	3.86	4.01
Lysine	4.03	4.33	4.28	3.93
Methionine	1.22	1.31	1.25	1.17
Phenylalanine	2.12	2.36	2.46	2.43
Threonine	1.71	1.88	1.96	1.97
Tryptophan	0.55	0.58	0.63	0.64
Valine	2.34	2.52	2.54	2.8

TABLE 5:

Apparent digestibility coefficients (ADCs) of nutrients of the experimental diets with graded inclusion levels of Ultra-High Protein, Low Oligosaccharide (UHP-LO) soybean meal (SBM) fed to Atlantic salmon

ADC (%)	Diet (%, as-fed)				
	Diet 1 (Reference - SPC)	Diet 2 (UHP-LO SBM 90:10)	Diet 3 (UHP-LO SBM 80:20)	Diet 4 (UHP-LO SBM 70:30)	P-value
Crude lipid	97.5 (0.3)	95.9 (0.5)	96.3 (0.3)	96.1 (0.5)	0.0764
Crude protein	83.0 (0.4)[d]	85.8 (0.3)[c]	89.2 (0.1)[a]	87.6 (0.3)[b]	<0.0001
Gross energy	73.3 (0.4)[c]	75.7 (0.2)[b]	79.7 (0.3)[a]	79.0 (0.1)[a]	<0.0001
Arginine	86.1 (0.6)[c]	89.2 (0.0)[b]	92.3 (0.3)[a]	91.0 (0.2)[a]	<0.0001
Histidine	90.5 (0.1)[c]	91.8 (0.2)[b]	93.6 (0.1)[a]	90.9 (0.2)[c]	<0.0001
Isoleucine	90.4 (0.2)[b]	90.9 (0.2)[b]	93.0 (0.1)[a]	90.8 (0.3)[b]	<0.0001
Leucine	89.4 (0.3)[b]	90.3 (0.2)[b]	92.2 (0.1)[a]	89.9 (0.3)[b]	0.0001
Lysine*	91.4 (0.2)[b]	92.8 (0.1)[ab]	94.5 (0.1)[a]	91.8 (0.2)[ab]	0.0005
Methionine	88.6 (0.5)[c]	91.4 (0.2)[b]	92.9 (0.2)[a]	91.2 (0.3)[b]	<0.0001
Phenylalanine*	88.2 (0.3)[b]	89.6 (0.2)[ab]	92.0 (0.1)[a]	89.3 (0.2)[ab]	0.0003
Threonine*	82.8 (0.4)[b]	85.5 (0.5)[ab]	88.8 (0.1)[a]	85.8 (0.3)[ab]	0.0005
Tryptophan	92.3 (0.0)[c]	93.4 (0.2)[b]	94.9 (0.2)[a]	92.3 (0.3)[c]	<0.0001
Valine*	87.7 (0.3)[b]	89.4 (0.2)[ab]	91.5 (0.1)[a]	89.9 (0.3)[ab]	0.0006

* Kruskal-Wallis was used to analyze non-parametric data.

TABLE 6:

Apparent digestibility coefficients (ADCs) of nutrients of Ultra-High Protein, Low Oligosaccharide (UHP-LO) soybean meal (SBM) fed to Atlantic salmon

ADC (%)	Diet (%, as-fed)				
	10% UHP-LO SBM	20% UHP-LO SBM	30% UHP-LO SBM	Mean	P-value
Crude protein	106.7 (2.5)[a]	109.5 (0.5)[a]	96.3 (0.9)[b]	104.2	0.0022
Gross energy	100.5 (2.6)[b]	108.4 (1.6)[a]	93.9 (0.2)[b]	100.9	0.0031
Arginine (Arg)	106.9 (0.3)[a]	107.9 (1.0)[a]	98.3 (0.6)[b]	104.4	0.0001
Histidine (His)	102.1 (1.7)[a]	104.0 (0.6)[a]	91.8 (0.6)[b]	99.3	0.0004
Isoleucine (Ile)	94.8 (1.7)[b]	101.0 (0.3)[a]	91.7 (0.8)[b]	95.8	0.0025
Leucine (Leu)	96.4 (1.6)[a]	100.8 (0.2)[a]	90.8 (0.8)[b]	96	0.0016
Lysine (Lys)*	107.2 (1.0)[ab]	108.1 (0.6)[a]	93.0 (0.8)[b]	102.8	0.0179
Methionine (Met)	129.8 (3.1)[a]	119.2 (1.1)[b]	100.3 (1.5)[c]	116.4	0.0002
Phenylalanine (Phe)	98.8 (1.3)[b]	102.6 (0.3)[a]	91.0 (0.6)[c]	97.5	0.0002
Threonine (Thr)	103.3 (3.5)[a]	106.5 (0.6)[a]	91.0 (0.9)[b]	100.2	0.0045
Tryptophan (Tryp)	100.6 (1.7)[a]	102.3 (0.7)[a]	92.3 (0.8)[b]	98.4	0.0019
Valine (Val)	102.0 (1.7)[a]	104.0 (0.5)[a]	94.1 (0.9)[b]	100.1	0.0019

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About Confluence

Confluence Genetics is a seed innovation company where the forces of nature and technology converge—unlocking the genetic diversity of soy quality traits through proprietary genetics, its AI-driven CropOS® platform, and its Crop Accelerator. Confluence Genetics collaborates with strategic partners throughout the agribusiness value chain to meet the demand for better feed, food, and fuel. More information can be found at confluence.ag.

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