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HENAN NORMAL UNIVERSITY

厚德博学·止于至善

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The oil fraction and partially defatted meal of black soldier fly larvae (*Hermetia illucens*) affect differently growth performance, feed efficiency, nutrient deposition, blood glucose and lipid digestibility of rainbow trout (*Oncorhynchus mykiss*)



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虹鳟



1.前言

解决鱼粉和鱼油的供需矛盾，促进水产养殖行业的可持续发展。





- 大菱鲂Kroeckel et al., 2012、太平洋白虾Cummins et al., 2017、虹鳟Renna et al., 2017 和建鲤Li et al., 2017 进行了部分脱脂粉替代研究，替代水平从2.6%-75.6%。

- 鱼油主要是在脂质需求量低的水产动物进行研究Li et al., 2017



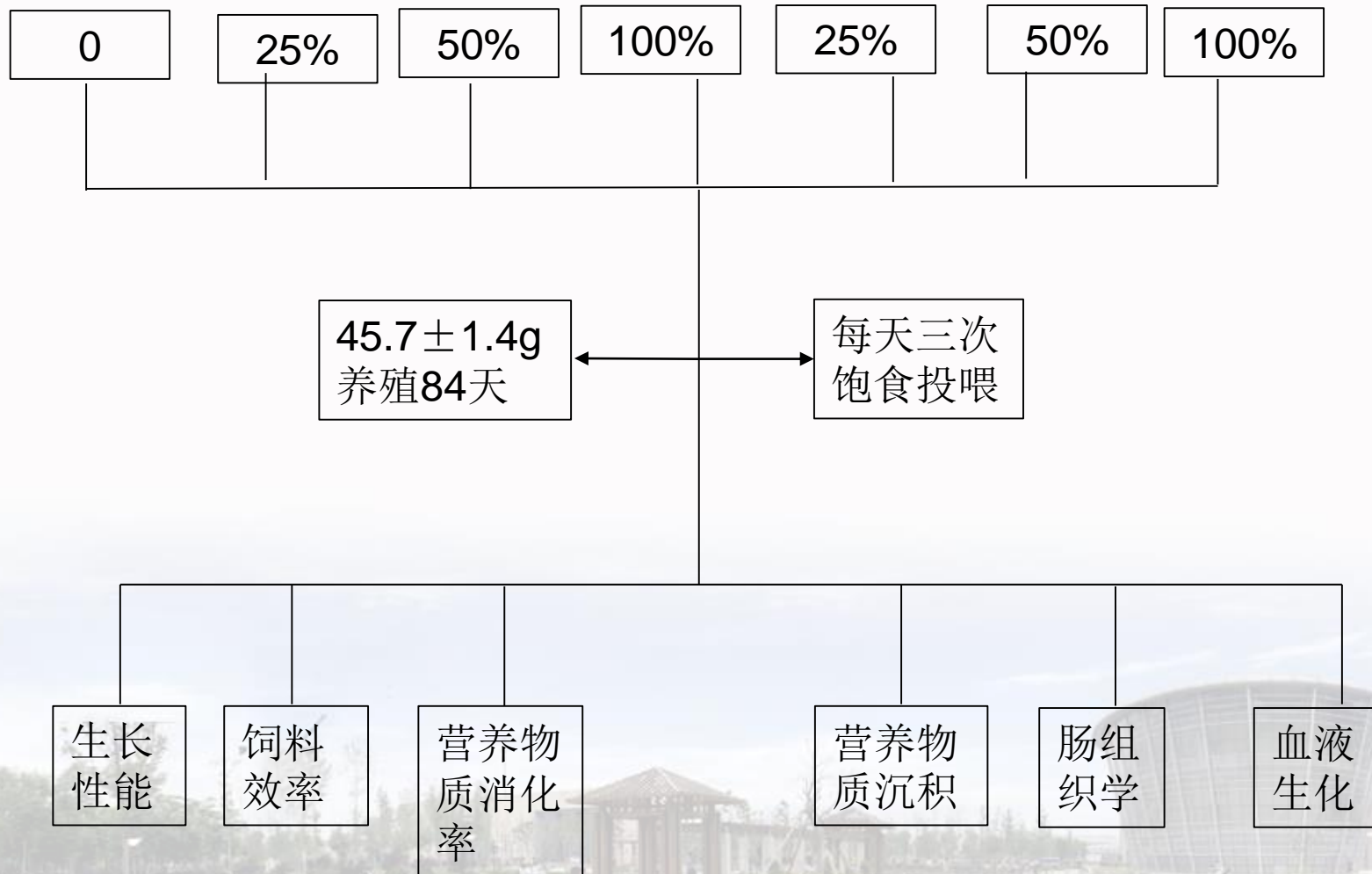
1.前言

本研究主要内容

通过研究虹鳟鱼的**生长性能**，**饲料效率**，**营养物质消化率和沉积**，**肠组织学和血液生化**等指标来确定脱脂黑水虻和黑水虻油的最适添加水平。



2.材料方法



3.结果

生长指标

Table 3

Initial (IBW) and final (FBW) body weight, weight gain (WG), thermal-unit growth coefficient (TGC), feed intake (FI), feed conversion ratio (FCR), survival and hepatosomatic index (HSI) of rainbow trout fed the black soldier fly larvae meal (BSFLM) and oil (BSFLO) experimental diets.*

Diet	IBW (g/fish)	FBW (g/fish)	WG (g/fish)	TGC (g ^{1/3} /°C*d)	FI (g/fish)	FCR**	Survival (%)	HSI (%)
A (control)	47.8 (1.9)	341.5 (6.0) ^a	293.7 (4.9) ^a	0.289 (0.005) ^a	232.7 (3.5)	0.78 (0.01) ^d	96.7 (0.0)	1.79 (0.16) ^b
B (6.6BSFLM)	45.5 (1.2)	325.7 (11.6) ^a	280.2 (10.5) ^a	0.286 (0.004) ^a	225.8 (8.5)	0.81 (0.02) ^c	98.9 (1.9)	1.90 (0.21) ^{a,b}
C (13.2BSFLM)	46.6 (0.8)	319.2 (5.5) ^a	272.6 (4.7) ^a	0.279 (0.004) ^a	229.7 (9.9)	0.84 (0.01) ^b	98.9 (1.9)	1.98 (0.15) ^{a,b}
D (26.4BSFLM)	45.9 (0.1)	286.6 (12.1) ^b	240.6 (2.1) ^b	0.260 (0.010) ^b	219.7 (13.0)	0.91 (0.00) ^a	98.9 (1.9)	2.10 (0.31) ^a
E (2.5BSFLO)	45.2 (1.3)	320.8 (11.2) ^a	275.6 (10.0) ^a	0.283 (0.006) ^a	213.7 (3.3)	0.78 (0.02) ^d	100.0 (0.0)	1.90 (0.22) ^{a,b}
F (5.0BSFLO)	46.5 (1.6)	335.7 (11.1) ^a	289.2 (11.1) ^a	0.288 (0.005) ^a	227.7 (10.2)	0.78 (0.01) ^{c,d}	98.9 (1.9)	1.78 (0.14) ^b
G (10.0BSFLO)	47.8 (1.7)	322.5 (1.1) ^a	274.7 (1.7) ^a	0.278 (0.004) ^a	214.3 (5.7)	0.77 (0.01) ^d	96.7 (5.7)	1.88 (0.13) ^b
ANOVA P-value	0.1772	0.0001	< 0.0001	0.0003	0.0834	< 0.0001	0.6599	0.0004

结果：体重增加量、生长系数、采食量、饲料转化率、存活率和肝脏系数数据显示，替代浓度不易超过26.4%。

3.结果

TGC与BSFLM的关系

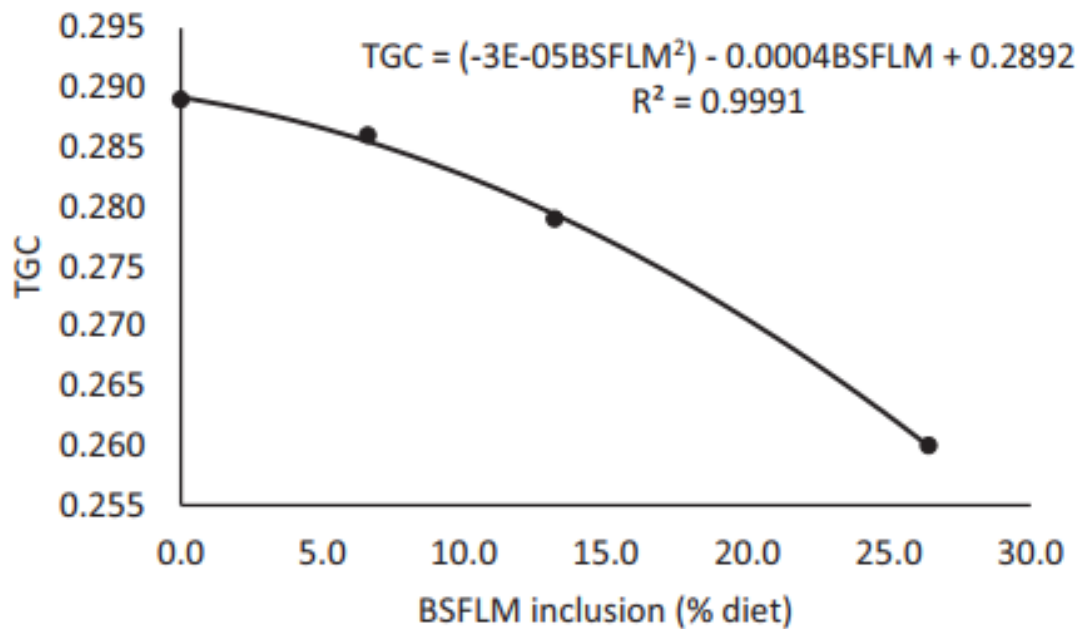
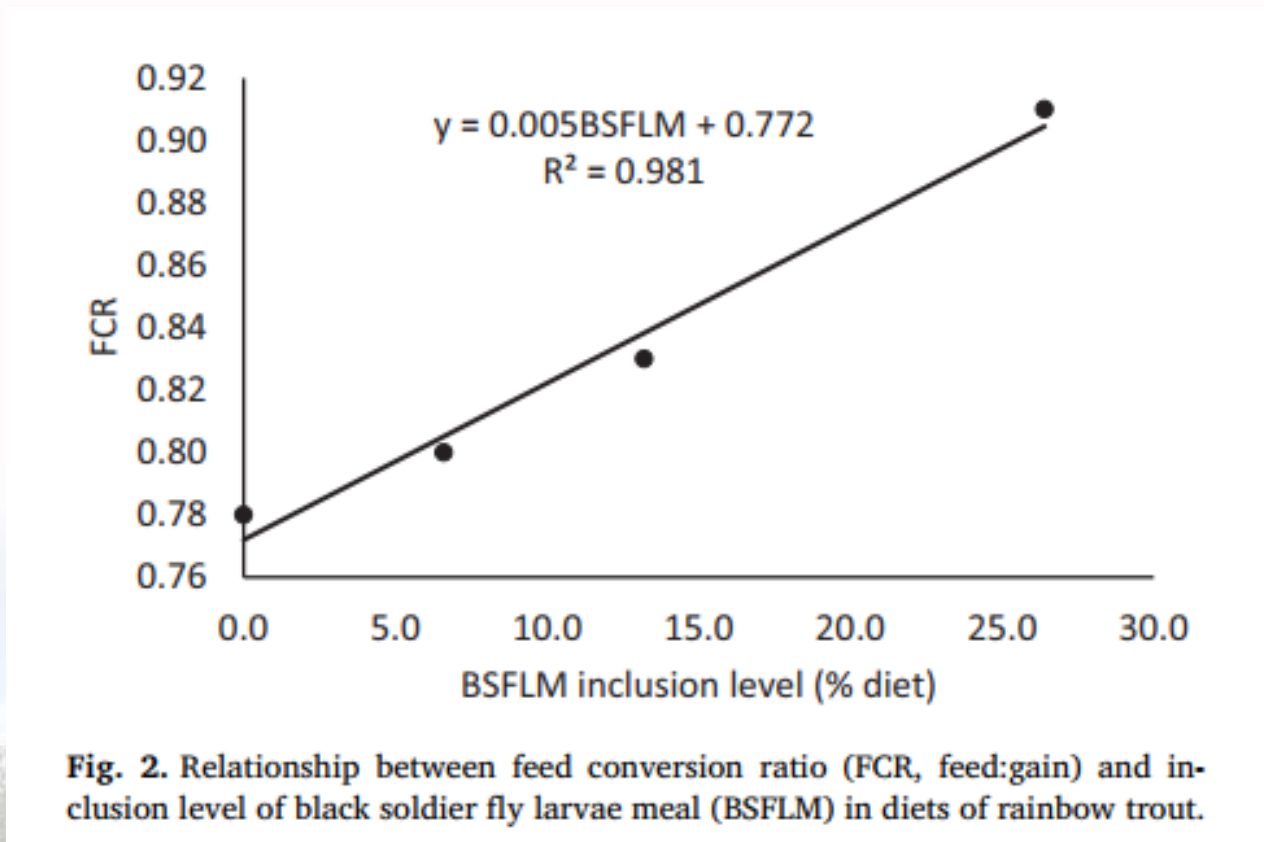


Fig. 1. Relationship between growth rate (TGC) and inclusion level of black soldier fly larvae meal (BSFLM) in diets of rainbow trout.



3.结果

FCR与BSFLM的关系



3.结果

Table 4

Bulk density (BD) and buoyancy (% floating pellets) of the experimental diets*. Pellets that stayed at the water surface for 30 s or more were considered as floating.

Diet	BD (g/l)	Buoyancy (% floating pellets)
A (Control)	516.4 (9.5) ^a	80
B (6.6BSFLM)	490.9 (7.4) ^b	90
C (13.2BSFLM)	496.1 (4.7) ^{a,b}	70
D (26.4BSFLM)	481.5 (16.8) ^b	100
E (2.5BSFLO)	457.1 (7.1) ^c	100
F (5.0BSFLO)	446.2 (1.6) ^c	100
G (10.0BSFLO)	445.7 (2.4) ^c	100
ANOVA <i>P</i> -value	< 0.0001	0.1153

饲料密度在正常范围内，且大多数饲料颗粒处于浮动状态，适合饲喂虹鳟鱼。



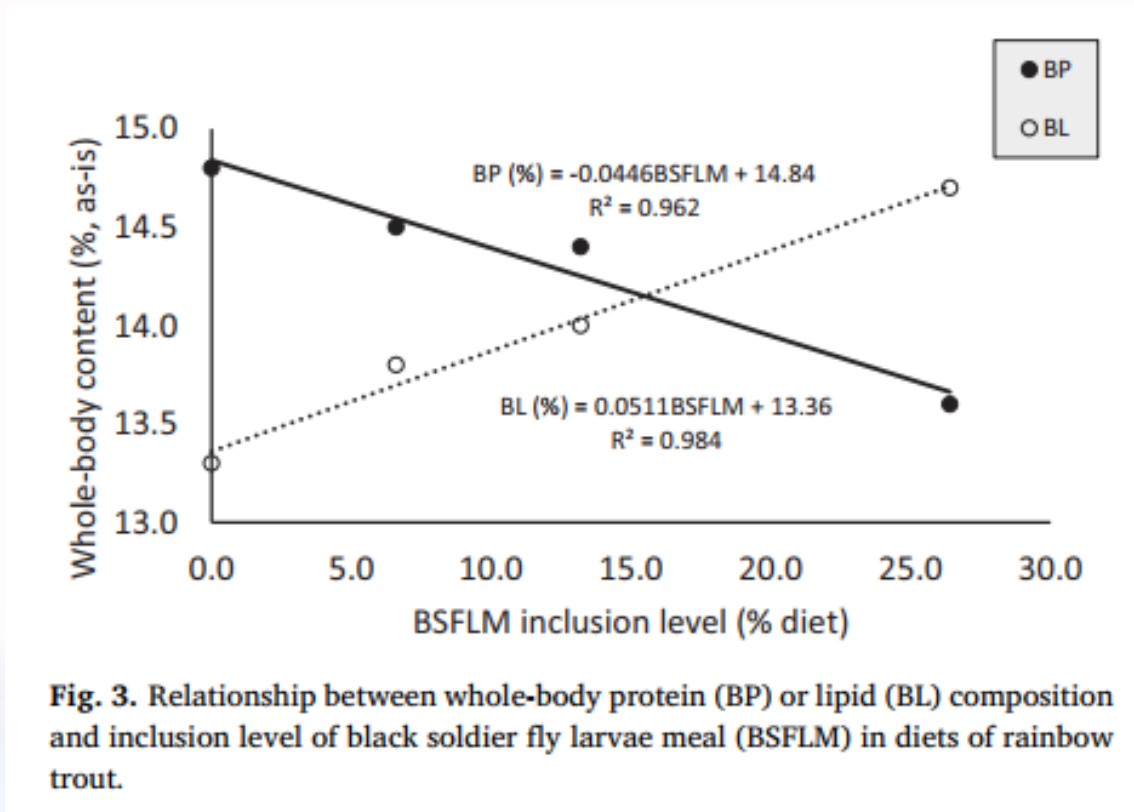
3.结果

Table 5
Whole-body proximate and amino acid composition (%*, as-is*) of rainbow trout fed diets containing graded levels of black soldier fly larvae meal (BSFLM) and oil (BSFLO)*.

Nutrient	Diet (% <i>, as-is</i>)							ANOVA P-value
	A (Control)	B (6.6BSFLM)	C (13.2BSFLM)	D (26.4BSFLM)	E (2.5BSFLO)	F (5.0BSFLO)	G (10.0BSFLO)	
Moisture	70.0 (0.3)	70.2 (0.7)	70.2 (0.3)	69.8 (0.4)	69.8 (0.5)	69.4 (0.3)	70.3 (0.5)	0.218
Crude protein	14.8 (0.3) ^a	14.5 (0.3) ^a	14.4 (0.1) ^{a,b}	13.6 (0.4) ^b	14.9 (0.3) ^a	15.0 (0.2) ^a	15.0 (0.4) ^a	0.000
Crude lipid	13.3 (0.4) ^{c,d}	13.8 (0.3) ^{b,c}	14.0 (0.2) ^{a,b,c}	14.7 (0.1) ^a	13.9 (0.1) ^{a,b,c}	14.3 (0.6) ^{a,b}	12.8 (0.3) ^d	0.000
Ash	1.71 (0.07)	1.81 (0.05)	1.80 (0.12)	1.81 (0.18)	1.74 (0.07)	1.70 (0.17)	1.68 (0.05)	0.631
Arginine	0.82 (0.02) ^{a,b}	0.83 (0.03) ^{a,b}	0.79 (0.02) ^{a,b}	0.76 (0.02) ^b	0.79 (0.08) ^{a,b}	0.86 (0.02) ^a	0.85 (0.02) ^{a,b}	0.035
Histidine	0.38 (0.01) ^a	0.38 (0.02) ^a	0.36 (0.01) ^{a,b}	0.33 (0.01) ^b	0.36 (0.04) ^{a,b}	0.39 (0.00) ^a	0.39 (0.01) ^a	0.006
Hydroxyproline	0.11 (0.00) ^b	0.14 (0.03) ^{a,b}	0.14 (0.02) ^{a,b}	0.15 (0.01) ^{a,b}	0.12 (0.04) ^{a,b}	0.18 (0.02) ^a	0.15 (0.03) ^{a,b}	0.035
Isoleucine	0.68 (0.02) ^a	0.66 (0.02) ^{a,b}	0.66 (0.03) ^{a,b}	0.60 (0.02) ^b	0.64 (0.04) ^{a,b}	0.68 (0.00) ^a	0.68 (0.01) ^a	0.005
Leucine	1.05 (0.04) ^a	1.02 (0.03) ^{a,b}	1.00 (0.03) ^{a,b}	0.94 (0.02) ^b	0.98 (0.07) ^{a,b}	1.05 (0.00) ^a	1.05 (0.01) ^a	0.007
Lysine	1.18 (0.03) ^a	1.16 (0.04) ^{a,b}	1.14 (0.03) ^{a,b}	1.05 (0.03) ^b	1.12 (0.08) ^{a,b}	1.20 (0.00) ^a	1.20 (0.02) ^a	0.004
Methionine	0.41 (0.01) ^{a,b}	0.41 (0.01) ^{a,b}	0.41 (0.01) ^{a,b}	0.38 (0.01) ^b	0.40 (0.03) ^{a,b}	0.42 (0.01) ^a	0.42 (0.01) ^a	0.019
Phenylalanine	0.60 (0.01) ^a	0.60 (0.02) ^{a,b}	0.58 (0.02) ^{a,b}	0.54 (0.02) ^b	0.56 (0.05) ^{a,b}	0.61 (0.00) ^a	0.60 (0.02) ^a	0.012
Taurine	0.11 (0.00)	0.10 (0.01)	0.11 (0.01)	0.11 (0.01)	0.10 (0.01)	0.11 (0.01)	0.11 (0.01)	0.594
Threonine	0.60 (0.02) ^{a,b}	0.59 (0.01) ^{a,b}	0.59 (0.01) ^{a,b}	0.55 (0.02) ^b	0.57 (0.05) ^{a,b}	0.61 (0.00) ^{a,b}	0.61 (0.01) ^a	0.037
Tryptophan	0.21 (0.02) ^{a,b}	0.20 (0.02) ^b	0.20 (0.02) ^b	0.20 (0.03) ^b	0.20 (0.02) ^{a,b}	0.22 (0.02) ^{a,b}	0.26 (0.03) ^a	0.026

粗蛋白与BSFLM呈负相关，粗脂肪与BSFLM呈正相关，组氨酸、异亮氨酸、亮氨酸、赖氨酸及苯丙氨酸显著性差异

3.结果



BP与BSFLM包含水平呈负相关，LP与BSFLM呈正相关

3.结果

肌肉常规组份含量

Table 6

Fillet (skinless) proximate composition of rainbow trout fed diets containing graded levels of black soldier fly larvae meal (BSFLM) and oil (BSFLO)*.

Nutrient	Diet (% as-is)							ANOVA P-value
	A (Control)	B (6.6BSFLM)	C (13.2BSFLM)	D (26.4BSFLM)	E (2.5BSFLO)	F (5.0BSFLO)	G (10.0BSFLO)	
Moisture	72.1 (0.1)	71.8 (0.9)	71.9 (0.8)	72.1 (1.0)	72.7 (1.1)	71.4 (0.4)	72.0 (0.4)	0.509
Crude protein	21.0 (0.9)	21.7 (0.5)	20.8 (0.8)	19.8 (0.5)	20.3 (0.5)	21.6 (1.1)	21.2 (1.6)	0.225
Crude lipid	6.7 (0.5)	6.7 (0.9)	7.1 (0.6)	8.0 (1.3)	6.2 (0.7)	6.9 (0.5)	6.6 (0.2)	0.182
Ash	1.37 (0.05)	1.41 (0.08)	1.33 (0.02)	1.33 (0.07)	1.35 (0.04)	1.36 (0.01)	1.36 (0.02)	0.460

肌肉常规组份不受BSFLM和BSFLO包含水平的影响



3.结果

营养物质沉积的速率和效率

Table 7

Rate and efficiency of selected nutrient deposition (as-is) in rainbow trout fed diets containing graded levels of black soldier fly larvae meal (BSFLM) and oil (BSFLO)*. PD, LysD, HypD and LD are rates of protein, lysine, hydroxyproline and lipid deposition (mg/°C*d), respectively; ePD, eLysD, eHypD and eLD are efficiencies of protein, lysine, hydroxyproline and lipid deposition (%), respectively.

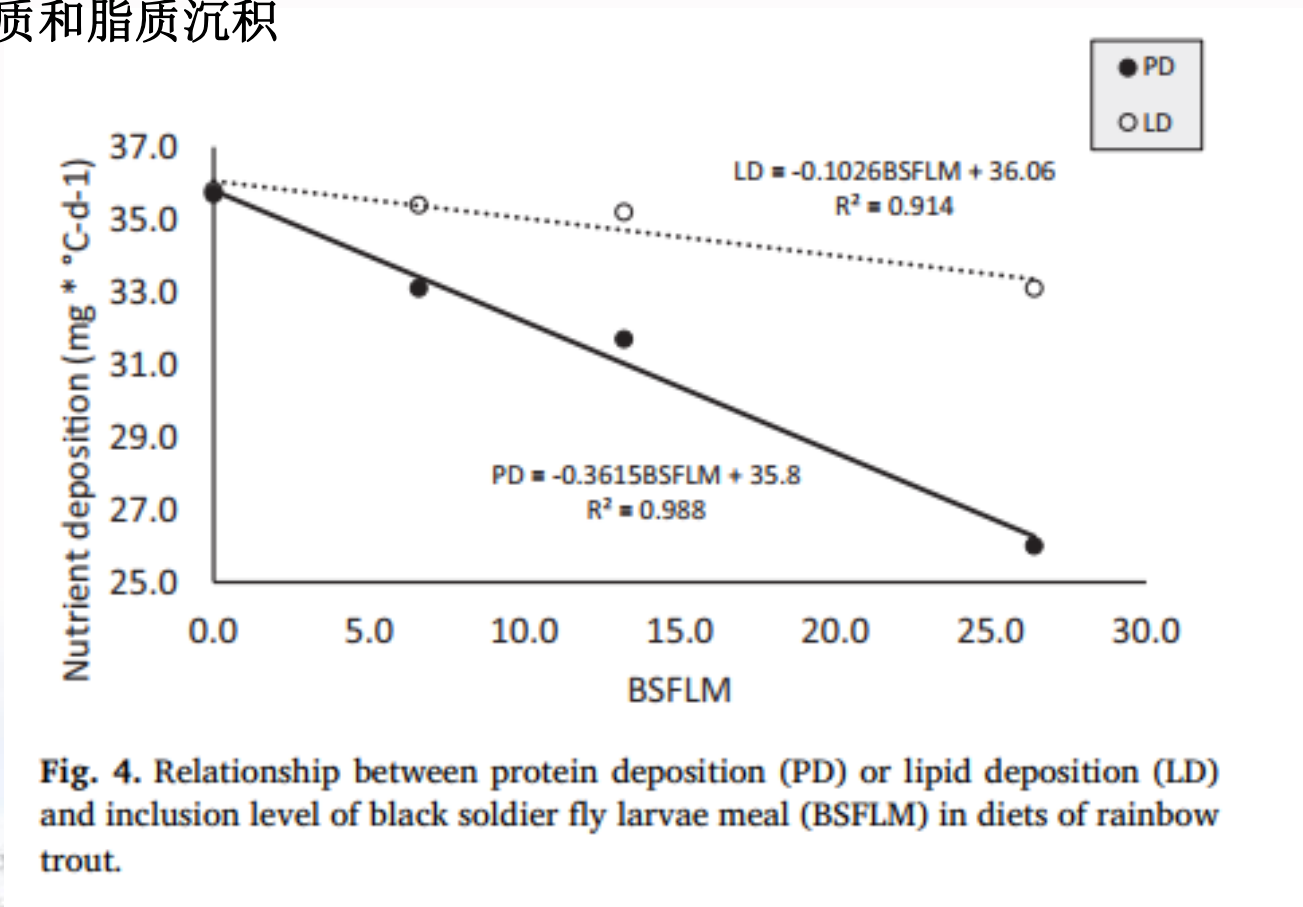
Nutrient deposition	Diet							ANOVA P-value
	A (Control)	B (6.6BSFLM)	C (13.2BSFLM)	D (26.4BSFLM)	E (2.5BSFLO)	F (5.0BSFLO)	G (10.0BSFLO)	
PD (mg/°C*d)	35.7 (1.1) ^a	33.1 (1.3) ^{a,b}	31.7 (0.9) ^b	26.0 (1.7) ^c	33.4 (0.9) ^{a,b}	35.5 (1.7) ^a	33.9 (0.8) ^{a,b}	0.000
ePD (%)	36.3 (1.1) ^{a,b}	35.1 (0.5) ^{a,b}	33.9 (0.1) ^b	29.6 (0.9) ^c	36.3 (0.5) ^{a,b}	35.8 (1.0) ^{a,b}	37.1 (1.4) ^a	0.000
LysD (mg/°C*d)	2.87 (0.09) ^a	2.66 (0.17) ^{a,b}	2.52 (0.14) ^b	2.00 (0.12) ^c	2.50 (0.14) ^b	2.87 (0.11) ^a	2.73 (0.03) ^{a,b}	0.000
eLysD (%)	54.4 (1.9) ^a	53.5 (1.1) ^{a,b}	53.8 (1.3) ^{a,b}	50.9 (1.6) ^{a,b}	49.2 (3.4) ^b	52.1 (0.8) ^{a,b}	54.7 (1.3) ^a	0.019
HypD (mg/°C*d)	0.25 (0.01) ^b	0.33 (0.06) ^{a,b}	0.32 (0.06) ^{a,b}	0.30 (0.02) ^{a,b}	0.25 (0.09) ^b	0.45 (0.07) ^a	0.34 (0.07) ^{a,b}	0.016
eHypD (%)	19.1 (0.1)	27.0 (6.1)	20.3 (4.3)	18.0 (0.8)	24.0 (8.9)	28.8 (4.6)	30.8 (6.2)	0.056
LD (mg/°C*d)	35.8 (0.5) ^{a,b}	35.4 (1.1) ^{a,b,c}	35.2 (1.2) ^{a,b,c}	33.1 (1.9) ^{b,c}	35.2 (1.3) ^{a,b,c}	37.9 (0.7) ^a	32.4 (1.0) ^c	0.001
eLD (%)	132.2 (3.7) ^a	128.3 (2.4) ^{a,b}	118.2 (1.6) ^b	107.0 (0.7) ^c	135.2 (2.7) ^a	134.1 (7.8) ^a	131.6 (4.6) ^a	0.000

BSFLM包含水平大于13.2%时PD、ePD、LysD及eLD的沉积效率显著降低



3.结果

蛋白质和脂质沉积



3.结果

肠道绒毛参数

Table 8

Villi length and width of the intestine of rainbow trout fed diets containing graded levels of black soldier fly larvae meal (BSFLM) and oil (BSFLO)*.

Intestine section	Diet							ANOVA P-value
	A (control)	B (6.BSFLM)	C (13.2BSFLM)	D (26.4BSFLM)	E (2.5BSFLO)	F (5.0BSFLO)	G (10.0BSFLO)	
Anterior intestine (AI)								
Length (μm)	1176.4 (159.52) ^a	1196.91 (192.84) ^a	1135.79 (285.95) ^{ab}	1034.66 (145.84) ^b	1141.13 (109.68) ^{ab}	1158.57 (120.20) ^{ab}	1130.21 (212.88) ^{ab}	0.0112
Width (μm)	186.21 (51.51)	177.49 (44.38)	174.57 (41.52)	170.30 (48.79)	175.97 (39.73)	168.68 (39.84)	168.01 (40.15)	0.5826
Posterior intestine (PI)								
Length (μm)	1156.19 (333.01)	1167.7 (314.28)	864.35 (259.27)	916.06 (264.50)	1046.54 (364.99)	1027.48 (289.23)	1020.4 (200.93)	0.1288
Width (μm)	151.68 (43.35)	150.94 (57.71)	128.62 (41.78)	154.57 (27.87)	131.01 (23.84)	141.03 (32.34)	162.44 (6.14)	0.5457

除了26.4BSFLM处理组前肠绒毛显著降低外，其他处理组的肠道结构没有受到影响。



3.结果

血液生化指标

Table 9

Analyte concentrations or activities from plasma samples of rainbow trout fed black soldier fly larvae meal (BSFLM) and oil (BSFLO) at graded dietary inclusion levels*. A:G is albumin to globulin ratio; K, potassium; Na, sodium; Cl, chloride; Ca, calcium; Phos, phosphorus; Mg, magnesium.

Parameters	Diet							ANOVA P-value
	A (Control)	B (6.6BSFLM)	C (13.2BSFLM)	D (26.4BSFLM)	E (2.5BSFLO)	F (5.0BSFLO)	G (10.0BSFLO)	
Glucose (mmol/l)	3.35 (0.46) ^b	3.99 (1.04) ^{a,b}	3.83 (0.98) ^{a,b}	3.57 (0.82) ^{a,b}	4.18 (0.70) ^a	3.51 (0.46) ^{a,b}	3.20 (0.31) ^b	0.0039
Cholesterol (mmol/l)	6.02 (0.87)	6.18 (1.14)	6.51 (1.47)	6.13 (0.95)	6.40 (1.46)	6.45 (1.28)	6.28 (1.25)	0.9218
Creatine kinase (U/l)	32,943 (39554)	24,906 (18219)	48,288 (62088)	59,493 (47917)	15,796 (6186)	39,674 (69394)	53,395 (156727)	0.6544
Total protein (g/l)	44.33 (2.94)	44.13 (3.50)	43.73 (4.01)	42.80 (3.61)	46.00 (3.64)	46.07 (3.10)	43.87 (2.39)	0.0825
Albumin (g/l)	16.73 (0.88)	17.00 (1.20)	17.00 (0.93)	16.20 (1.52)	17.40 (1.45)	17.27 (1.1)	16.60 (1.06)	0.1066
Globulin (g/l)	27.60 (2.26)	27.13 (2.56)	26.73 (3.28)	26.60 (3.00)	28.60 (2.41)	28.80 (2.57)	27.27 (1.98)	0.1430
A:G	0.61 (0.04)	0.63 (0.04)	0.64 (0.05)	0.62 (0.08)	0.61 (0.03)	0.60 (0.06)	0.61 (0.05)	0.4696
K (mmol/l)	1.55 (0.69)	1.52 (0.98)	1.67 (0.94)	1.83 (0.74)	1.13 (0.34)	1.20 (0.35)	1.65 (0.78)	0.0960
Na (mmol/l)	162.60 (2.23)	161.27 (2.22)	162.07 (2.55)	161.67 (2.53)	162.40 (2.67)	163.27 (2.12)	163.47 (1.64)	0.1024
Cl (mmol/l)	120.60 (2.29)	120.67 (2.79)	122.13 (2.61)	120.13 (3.02)	120.67 (2.41)	121.53 (2.72)	122.47 (1.51)	0.1015
Ca (mmol/l)	3.29 (0.12)	3.29 (0.19)	3.30 (0.13)	3.24 (0.21)	3.37 (0.18)	3.40 (0.13)	3.32 (0.15)	0.1448
Phos (mmol/l)	7.86 (0.71) ^{a,b}	7.12 (1.10) ^b	7.36 (0.84) ^{a,b}	8.11 (0.92) ^a	7.06 (0.85) ^b	7.51 (0.81) ^{a,b}	7.64 (0.66) ^{a,b}	0.0093
Mg (mmol/l)	1.55 (0.09) ^{b,c,d}	1.61 (0.14) ^{a,b,c}	1.51 (0.11) ^{c,d}	1.68 (0.12) ^a	1.66 (0.12) ^{a,b}	1.58 (0.11) ^{a,b,c,d}	1.46 (0.06) ^d	< 0.001
Total bilirubin (mmol/l)	0.27 (0.46)	0.53 (0.52)	0.47 (0.83)	0.33 (0.49)	0.33 (0.49)	0.40 (0.51)	0.33 (0.49)	0.8676
Packed cell volume** (l/l)	45.47 (4.88)	46.80 (3.51)	46.60 (3.02)	44.13 (6.28)	47.20 (3.63)	47.73 (3.61)	45.07 (3.22)	0.2091

26.4BSFLO 组Mg含量显著增高；2.5BSFLO组的葡萄糖显著升高，且葡萄糖与BSFLO包含水平呈负相关

- ✓ 适量的BSFLM包含水平对生长及饲料利用率不会产生负面的影响
- ✓ 当BSFLM添加量超过13%，蛋白质和脂质沉积受损，某些氨基酸水平降低，肠道受损
- ✓ BSFLO对鱼类的影响非常小，添加量可以达到10%甚至更高

1. 确定BSFLO的最高添加水平
2. 阐明高含量BSFLM产生负面影响的因素有哪些





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恳请各位老师批评指正

