

翘嘴鲌鱼种对磷的需求量

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摘要:以磷酸二氢钠为磷源,制成含磷水平为0.53%—1.61%的7种半精制试验饲料,饲养7组三重复的翘嘴鲌隔冬鱼种。试验鱼每尾平均体重 3.79 ± 0.20 g。饲养期为8周。试验结果表明,饲料磷含量不足会导致鱼体生长不良,饲料效率低下。饲料磷为0.88%或以上时,鱼体增重和饲料效率显著提高。全鱼脂肪含量随饲料磷水平上升而呈下降趋势,但各试验组间无显著差异($p > 0.05$)。全鱼的粗灰分含量与饲料磷水平呈正相关。饲料磷水平为0.88%或更高时,全鱼磷含量和脊椎骨的灰分含量稳定在同一水平上。饲料磷水平对全鱼水分、全鱼粗蛋白、鳞片灰分、鳞片磷和脊椎骨磷含量无显著影响($p > 0.05$)。因此,满足翘嘴鲌鱼种生长所需的饲料磷为0.88%。

关键词:翘嘴鲌; 磷; 需求量; 鱼体增重; 饲料效率

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磷是鱼类坚硬组织如骨骼、鳞和牙齿的主要构成元素之一,又是体内核酸、磷脂、辅酶、DNA和RNA等含磷有机物的组成成分。鱼体内的无机态磷酸盐也是维持体液正常pH的重要缓冲物质^[1]。但天然水体内磷含量极其有限,养殖鱼类不可能从水环境中吸收足够的磷。因此,养殖鱼类从饲料中获取磷元素至关重要^[2]。另一方面,出于对水环境保护的考虑,鱼饲料中的磷水平不能过高^[3,4]。国内外的科学家进行了大量的实验,试图精确了解鱼类对饲料磷的最适需要量。迄今有关鱼类对磷需要量的报道值为:0.24%—1.22%^[1,4,5]。翘嘴鲌(*Culter alburnus*)是新兴淡水养殖品种,对磷的需求量尚未见报道。本文以翘嘴鲌为研究对象,通过梯度试验法,以期确定合适的饲料磷水平,为开发翘嘴鲌专用配合饲料提供理论依据。

1 材料与方法

1.1 试验饲料 以鱼粉、蚕蛹粉和酪蛋白为蛋白源,以磷酸二氢钠为磷源,用沸石粉调节百分比,制成含磷水平为0.53%—1.61%的7种半精制试验饲料,其设计配方的原料组成和营养成分见表1。试验饲料制作时,先将原料粉碎,使原料粉未能全部通

过孔径为0.355mm试验筛,再按比例混合和搅拌均匀后挤压成直径约为1.2mm的颗粒,风干后置于4℃冷藏箱中备用。

1.2 试验鱼及分组 试验鱼种取自本所实验鱼场同一培育池的隔冬鱼种,平均尾重 3.79 ± 0.20 g。试验前于水泥池用自制硬颗粒破碎料驯养2周后随机分养到7组三重复的21只试验水箱,每箱放鱼30尾。每组试验鱼的初始体重见表2,经方差检验,各组间试验鱼的初始体重无显著差异($p > 0.05$)。

1.3 饲养方法与水质 试验鱼饲养在容积为500L流水式圆形玻璃钢水箱中,内盛水300L。水源为经30ppm硫代硫酸钠处理后的曝气自来水,水中钙、磷含量分别为35.7mg/L和0.05mg/L。日水交换量250%,连续充气。每天从8:00至16:00投饲三次,每次均投饲至接近饱食。饲养试验持续8周。饲养期间,水温25—28℃;水质:pH 7.4—7.5, DO 6.11—6.48mg/L, $\text{NH}_3\text{-N}$ 0.26—0.28mg/L, $\text{NO}_2\text{-N}$ 0.035—0.066mg/L; $\text{NO}_3\text{-N}$ 0.25—0.35mg/L。

1.4 取样与化学分析 取制作完成的试验饲料、饲养试验开始时和完成后饥饿2d的试验鱼(每箱8尾)供营养成分测定。用试验完成后饥饿2d的试验鱼,每箱另取8尾,取磷片和脊椎骨,并参照相关文献的

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方法^[6,9]将脊椎骨中脂肪用乙醚抽提干净,烘干后备用。测定方法为: 105℃常压干燥法测定水分;微量凯氏定氮法测定粗蛋白;用无水乙醚为溶剂,索氏抽提法测定粗脂肪;箱式电阻炉 550℃灼烧法测定粗灰分;试验饲料样品经湿法预处理,鱼体、鱼鳞和脊椎骨样品经干法预处理后,用钒钼酸铵法测定磷含量。

1.5 指标及其计算 饲养试验结束后,对试验鱼进行称重和计数,统计总投饲量。成活率、鱼体增重和

饲料效率计算方法如下:

$$\text{成活率}(\%) = 100 \times (\text{收获尾数} / \text{放养尾数})$$
$$\text{鱼体增重}(\%) = 100 \times [(\text{鱼体终重} - \text{鱼体始重}) / \text{鱼体始重}]$$

$$\text{饲料效率} = \text{鱼体增重量} / \text{干饲料摄入量}$$

1.6 数理统计方法 各种数据在不同试验组间用方差分析进行显著性检验,如发现有显著差异($p < 0.05$),则作 Duncan 氏多重比较分析。

表 1 试验饲料组成和营养成份分析表(占干物质的百分比)
Tab.1 Composition and proximate analysis of trial diets (% of dry matter)

原 料 Ingredient	饲料编号(Diet No.)						
	1	2	3	4	5	6	7
鱼粉 Fish meal	10	10	10	10	10	10	10
蚕蛹 Silk worm pupae	26	26	26	26	26	26	26
酪蛋白 Casein	26	26	26	26	26	26	26
糊精 Dextrin	21.5	21.5	21.5	21.5	21.5	21.5	21.5
油 Oil	2	2	2	2	2	2	2
无磷无机盐 P-free mineral	5	5	5	5	5	5	5
维生素 Vitamin	0.5	0.5	0.5	0.5	0.5	0.5	0.5
纤维素 Cellulose	4	4	4	4	4	4	4
磷酸二氢钠 Mono-basic sodium phosphate	0	0.7	1.4	2.1	2.8	3.5	4.2
沸石粉 Zeolite	5	4.3	3.6	2.9	2.2	1.5	0.8
营养成分分析 Proximate analysis							
粗蛋白 Crude protein	41.08	41.05	40.86	40.91	40.86	41.17	41.10
粗脂肪 Crude lipid	9.22	9.47	9.22	9.49	9.69	9.81	9.65
粗灰分 Crude ash	12.56	12.54	12.41	12.64	12.38	12.62	12.78
磷 Phosphorus	0.53	0.70	0.88	1.07	1.26	1.43	1.61

表 2 鱼体生长情况(平均值±标准误)
Tab.2 The growth performance of fish fed trial diets for 8 weeks (Mean±SE)

饲料磷 Dietary phosphorus %	鱼体初始重 Initial body weight g	鱼体增重 Weight gain %	饲料效率 Feed efficiency	成活率 Survival rate %
0.53	3.97±0.07	73.77±2.96 ^a	0.47±0.01 ^a	87.78±4.84
0.70	3.75±0.08	83.16±1.92 ^a	0.49±0.02 ^a	92.22±4.01
0.88	3.78±0.11	141.85±15.47 ^b	0.74±0.01 ^b	94.44±4.01
1.07	3.83±0.18	123.55±8.79 ^b	0.69±0.09 ^b	91.11±1.11
1.26	3.80±0.12	124.29±18.11 ^b	0.69±0.08 ^b	92.22±1.11
1.43	3.61±0.13	123.57±7.54 ^b	0.67±0.05 ^b	93.33±3.33
1.61	3.79±0.10	119.31±6.01 ^b	0.66±0.03 ^b	90.00±5.77

注: 同一列数据有不同上标的英文字母表示有显著差异($p < 0.05$)
There is a significant difference between treatments with different sub-alphabet in one column($p < 0.05$)

2 结 果

2.1 鱼体生长情况

摄食含不同磷水平的试验饲料 8 周后,试验鱼的鱼体增重、饲料效率和成活率列于表 2 中。从表 2 中可以看到,饲料含磷量为 0.53% 和 0.70% 的两个试验组之间,试验鱼的鱼体增重无明显差异($p > 0.05$),但均显著低于其他各试验组的鱼体增重

($p < 0.05$)。饲料含磷量为 0.88%—1.61% 的五个试验组之间,试验鱼的鱼体增重也无明显差异($p > 0.05$);饲料效率受饲料磷水平影响的变化趋势与鱼体增重指标一致;饲养试验结束时,各试验组的鱼体成活率为 87.78%—94.44%,组间无显著差异($p > 0.05$)。因此,饲料磷含量不足会导致鱼体生长不良,饲料效率低下。当饲料磷水平上升至 0.88% 时,鱼体增重和饲料效率显著提高。

但饲料磷继续升高, 鱼体增重和饲料效率仍处于同一水平上。

2.2 全鱼营养组成

由表 3 可见, 试验鱼经 8 周饲养后, 全鱼的水分、粗蛋白和粗脂肪含量在各试验组间无显著差异 ($p > 0.05$), 没有受饲料磷水平的影响; 尽管全鱼中脂肪含量在各试验组间无显著差异, 但仍能看到全鱼脂肪含量随饲料磷水平上升而呈下降趋势 ($y = -0.74x + 3.75$, $r^2 = 0.9237$); 全鱼的粗灰分含量受饲料磷水平影响显著 ($p < 0.05$), 且随饲料磷水平

上升而不断增高, 成正相关关系 ($Y = 0.59X + 3.12$, $R^2 = 0.8839$)。

2.3 全鱼磷含量、脊椎骨和磷片中的灰分、磷含量

由表 4 可见, 饲料磷水平对全鱼磷和脊椎骨灰分含量有显著影响 ($p < 0.05$), 饲料含磷量为 0.53% 和 0.70% 的两个试验组中全鱼磷和脊椎骨灰分含量较低, 而当饲料含磷量上升至 0.88% 或以上时, 全鱼磷和脊椎骨灰分含量则显著上升并稳定在同一水平上。饲料磷水平对鳞片灰分、鳞片磷和脊椎骨磷含量无显著影响 ($p > 0.05$)。

表 3 全鱼营养组成(平均值±标准误)
Tab. 3 Proximate analysis of whole fish body (Mean±SE)

饲料磷 Dietary phosphorus %	水分 Moisture %	粗蛋白 Crude protein %	粗脂肪 Crude lipid %	粗灰分 Crude ash %
0.53	75.74±0.18	17.54±0.29	3.34±0.47	3.53±0.18 ^a
0.70	76.19±0.34	17.73±0.32	3.15±0.13	3.43±0.07 ^a
0.88	75.84±0.33	17.79±0.29	3.19±0.21	3.65±0.01 ^{ab}
1.07	76.14±0.24	17.48±0.19	2.98±0.17	3.67±0.10 ^{ab}
1.26	76.15±0.11	17.58±0.07	2.91±0.06	3.95±0.07 ^{bc}
1.43	75.83±0.08	17.92±0.13	2.56±0.18	3.89±0.09 ^{bc}
1.61	76.43±0.03	17.24±0.07	2.57±0.18	4.12±0.08 ^c

注: 同一列数据有不同上标的英文字母表示有显著差异($p < 0.05$)
Note: There is a significant difference between treatments with different sur-alphabet in one column($p < 0.05$)

表 4 全鱼磷含量、脊椎骨和磷片中的灰分及磷含量(平均值±标准误, 占干物质的百分比)
Tab. 4 Whole body phosphorus, ash and phosphorus in vertebrae and scale (Mean±SE, % of dry matter)

饲料磷 Dietary phosphorus	脊椎骨灰分 Vertebrae ash	鳞片灰分 Scale ash	全鱼磷 Whole body phosphorus	脊椎骨磷 Vertebrae phosphorus	鳞片磷 Scale phosphorus
0.53	51.46±0.40 ^a	21.71±0.53	2.67±0.09 ^a	9.77±0.08	3.89±0.08
0.70	51.98±0.44 ^a	21.32±0.53	2.70±0.03 ^a	9.58±0.11	3.89±0.13
0.88	54.01±0.46 ^b	21.46±1.31	2.78±0.07 ^{ab}	9.78±0.11	3.86±0.24
1.07	53.57±0.49 ^b	21.76±0.78	2.94±0.09 ^b	10.00±0.06	3.58±0.36
1.26	54.04±0.23 ^b	22.39±0.06	2.98±0.09 ^b	9.74±0.08	3.97±0.30
1.43	53.62±0.48 ^b	21.91±0.30	2.92±0.05 ^b	9.74±0.09	3.74±0.05
1.61	53.74±0.43 ^b	23.67±1.42	3.01±0.03 ^b	9.82±0.09	4.21±0.20

注: 同一列数据有不同上标的英文字母表示有显著差异($p < 0.05$)
Note: There is a significant difference between treatments with different sur-alphabet in one column($p < 0.05$)

3 讨 论

本试验观察到, 翘嘴鲌鱼种摄食含磷较低的两组试验饲料导致生长不良和饲料效率低下。当饲料磷升高到 0.88% 时, 鱼体增重和饲料效率显著提高, 但饲料磷含量继续上升, 鱼体增重和饲料效率并不能进一步改善。这说明在翘嘴鲌与其他养殖鱼类

饲料中须含有一定数量的磷, 但过高的饲料磷是不必要的。该现象与对其他养殖鱼类的研究观察相同^[1,2]。因此, 在本试验条件下, 满足翘嘴鲌鱼种最大生长所需的饲料磷为 0.88%。该数值落在其他鱼类磷需要量报道值的范围内, 与对红鼓鱼(0.87%)^[6]和异育银鲫(0.92%)^[7]的研究结果较为接近。

在研究鱼类对磷的需要量时, 全鱼或鱼的不同部位如脊椎骨和鳞片的灰分、钙和磷等的含量常被检测, 作为确定饲料中最适磷含量的参考指标。但不同的研究获得的变化规律并不甚一致。有研究认为, 只有当饲料磷严重缺乏时, 鱼体或组织中灰分、钙和磷才会受到影响, 从而认为这些指标只能反映出鱼类维持其机体磷平衡所需的饲料磷最低需要量, 该饲料磷水平不能满足鱼体最大生长的需要^[7-9]; 另一些研究则发现全鱼或胴体、骨骼和鳞片的灰分含量受到饲料磷的显著影响或两者呈正相关, 而胴体和骨骼中的磷含量却不受饲料磷的影响^[10-14]。但鱼体或组织的磷含量同时受饲料磷影响也有报道^[15-17]。本试验中, 当饲料磷为 0.88% 或更高时, 翘嘴鲌鱼种全鱼中的磷含量和脊椎骨的灰分含量才能达到稳定; 全鱼灰分含量随饲料磷上升而不断升高; 基础饲料磷水平(0.53%) 足以维持鳞片灰分、鳞片磷和脊椎骨磷含量的稳定。有研究认为, 鱼类摄食含磷量不足的饲料会导致鱼体脂肪含量升高^[8,14,18]。本试验结果与这一观点相同。这可能是同鱼摄取饲料磷的数量与体内脂肪的氧化速度存在联系有关^[18]。

通过在基础饲料中添加磷酸二氢钠的试验表明, 0.88% 的饲料磷能满足翘嘴鲌鱼种的生长需要, 并确保全鱼磷含量的稳定和脊椎骨的正常矿化。

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DIETARY PHOSPHORUS REQUIREMENT OF *CULTER ALBURNUS* FINGERLING

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Abstract: A feeding trial was conducted with water flow-through fiberglass tank systems to evaluate the dietary phosphorus requirement of *Culter alburnus* fingerling. Seven semi-purified diets containing phosphorus levels ranging from 0.53% to 1.61% were formulated by including graded levels of monobasic sodium phosphate. Test diets were fed to triplicate groups of 30 fingerlings initially weighing $3.79 \pm 0.20\text{g}$ /fish. Water temperature during the feeding trial was controlled at $27 \pm 2^\circ\text{C}$. The fish were hand-fed to approaching satiation three times a day for 8 weeks. The results show that fish fed the two diets with low levels of phosphorus (diet 1 and diet 2) have significantly lower weight gain and feed efficiency ($p < 0.05$) than those of fish fed the test diets with phosphorus levels of 0.88% and above (diet 3, diet 4, diet 5, diet 6 and diet 7), and there are no significant differences ($p > 0.05$) between treatments of diet 1 and diet 2 and among treatments of diet 3, diet 4, diet 5, diet 6 and diet 7; the survival rate of fish is not affected by the levels of dietary phosphorus. It was also observed that, at the end of feeding trial, the whole body lipid has a tendency to decrease with the increment of dietary phosphorus levels, even though there is no significant difference among treatments ($p > 0.05$); the whole body ash is affected significantly ($p < 0.05$) by dietary phosphorus levels, and seems to have positive correlation to dietary phosphorus levels, but there are no significant differences ($p > 0.05$) among fish groups fed diets of 1 to 4, of 3 to 6 and of 5 to 7, respectively; whole body phosphorus is significantly lower ($p > 0.05$) when the fish fed two diets with phosphorus levels of less than 0.88%, and reaches to a plateau when the fish fed diets with phosphorus levels of 0.88% and more; vertebrae ash appears to have similar responses to the levels of dietary phosphorus as whole body phosphorus; there is no significant difference ($p > 0.05$) of whole body moisture, whole body protein, scale ash, scale phosphorus and vertebrae phosphorus among test groups. It can be concluded that the dietary phosphorus requirement for *C. alburnus* fingerling is approximately 0.88% of dry diet, which was important for this species to maintain the normal growth and vertebrae mineralisation as well as a stable level of whole body phosphorus.

Key words: *Culter alburnus*; Phosphorus; Requirement; Weight gain; Feed efficiency