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Development of Formula Diet and Current Situation of Culture Industry of Korean Rockfish *Sebastes schlegeli*

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Abstract

Korean rockfish, *Sebastes schlegeli*, which was famous for its delicious and nutritious meat, rapid growth and strong disease resistance, has become one of mainly cultured fish species in deep-water cages in northern China. With the development of industry and the adjustment of policy, it has been an urgent problem to be solved to develop the high quality and efficiency formula diet for this species. In order to provide reference for the development of industry, the requirements of main nutrients, the stress of water environment factors, the selection of suitable raw materials and functional feed additives in formula diet, and the use of formula diet were summarized in this paper. In addition, the existing problems of rockfish aquaculture industry, and the future development direction were also analyzed.

Keywords

Korean Rockfish *Sebastes schlegeli*, Formula Diet, Culture Industry

许氏平鲉配合饲料的研究进展及产业发展现状

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摘　要

许氏平鲉营养丰富、肉质鲜美、生长迅速、抗病力强，是我国北方深水网箱养殖的主要鱼类之一。随着产业的发展和政策的调整，许氏平鲉优质高效专用配合饲料的开发成为亟待解决的问题。本文综述了许氏平鲉对主要营养素的需求、水环境因素对其的胁迫、配合饲料中适宜原料及功能性饲料添加剂的选择，并对配合饲料的使用技术做了总结，以期为产业的发展提供参考。此外，本文还分析了许氏平鲉养殖产业存在的问题，并展望了未来的发展方向。

关键词

许氏平鲉，配合饲料，养殖

1. 引言

许氏平鲉(Korean rockfish，*Sebastes schlegeli*)，又名黑鲳、黑头、黑寨，隶属于鲉形目(*Scorpaeniformes*)、鲉科(*Sebastidae*)、平鲉属(*Sebastes*)，是我国渤海、黄海、东海以及朝鲜半岛、日本、鄂霍次克海均有分布的一种近岸冷水肉食性鱼类。自然条件下许氏平鲉洄游范围小，一般栖息在岩礁附近水域，适宜人工鱼礁资源增殖和网箱养殖，目前已成为我国北方沿海重要的海水增殖放流及养殖鱼类之一。随着产业的发展，养殖投入品供应不足、养殖自身污染的问题日益凸显，开发优质高效的许氏平鲉专用配合饲料成为亟待解决的问题。营养需求、消化生理、原料开发和添加剂的筛选等是配合饲料开发的基础。关于许氏平鲉营养需求及饲料开发的研究起始于上世纪九十年代，且以韩国科学家报道为主。因此，本文综述了相关方面的研究进展，以期为我国许氏平鲉优质高效配合饲料的开发及增养殖产业的发展提供参考。

2. 许氏平鲉营养需求研究

由表 1 可见，目前关于许氏平鲉营养需求的研究相对较多，也较为全面。随着体重的增加，许氏平鲉对蛋白质的需求量下降[1] [2] [3]。仔稚鱼阶段的蛋白质需求约占饲料的 50%；养成阶段推荐饲料蛋白质含量为 40%。提高饲料中的粗脂肪、能量含量能起到节约蛋白质的作用[4] [5]。从文献分析，许氏平鲉对脂肪的需求并不高，饲料中 6%的粗脂肪已能满足其需求[6]。体重 3.6 g 的许氏平鲉幼鱼饲料中适宜的碳水化合物脂肪比为 1.6，而 166 g 时适宜的碳水化合物脂肪为 0.4~5.6，表明在其养成阶段，碳水化合物可以替代部分脂肪[7]。许氏平鲉对饲料中赖氨酸、蛋氨酸的需求量分别为 2.99%和 1.37%饲料[8] [9]，同时，饲料中添加适量的牛磺酸能促进胆汁酸的合成[10]。饲料中必需脂肪酸含量应高于 1.2% [11]，且 EPA 和 DHA 的适宜含量均为 1%，DHA 要优于 EPA [12]。n-3HUFA 对许氏平鲉有重要的生理意义，且含量应高于 0.9% [13] [14] [15] [16]。β-胡萝卜素、虾青素、叶黄素、角黄素是许氏平鲉体内主要的类胡萝卜素，也是影响其体色的重要元素[17]。许氏平鲉对饲料中维生素 C 及维生素 E 的需求量分别为 106 mg/kg 和 45 mg/kg [18] [19] [20] [21]，不同形式的维生素 C 均可作为其体内维生素 C 的来源。Lee S M 等给出了许氏平鲉配合饲料中各维生素推荐量[22]。P、Ca、Zn、Mg 等是许氏平鲉正常生长所必须的矿物元素[23] [24]，

Table 1. Nutrients requirements of Korean rockfish *Sebastes schlegeli*
表 1. 许氏平鲉的营养需求

营养素 Nutrients	鱼体重 Body weight	结果 Results	文献来源 References
蛋白质 protein	8 g, 220 g	40%蛋白满足 8~300 g 鱼生长需求	Lee J Y *et al*. [1]
	7.3 g	大于 48.6%，小于 50%	Kim K W *et al*. [2]
蛋白质，脂肪 protein, lipid	21.9 g	42%DP，14%DL	Lee S M *et al*. [3]
	3.22 g	50%，15%或 45%，19%	Cho S H *et al*. [4]
蛋白质能量比 ratio of protein to energy	36 g, 80 g	45%或 40%粗蛋白，能量为 8 kcal/g 蛋白	Lee J Y *et al*. [5]
脂肪 lipid	7.13 g	6%	Song L P *et al*. [6]
糖脂比 ratio of carbohydrate to lipid	3.6 g, 166 g	幼鱼 1.6，养成鱼 0.4~5.6	Lee S M *et al*. [7]
赖氨酸 Lys	28.42 g	2.99%饲料，6.16%饲料蛋白	严全根等 [8]
蛋氨酸 Met	43.61 g	1.37%饲料，2.8%粗蛋白，Cys1.2%	Yan *et al*. [9]
牛磺酸 taurine	13.5 g	牛磺酸是合成结合胆汁酸的唯一原料	Kim S K *et al*. [10]
必须脂肪酸 EFA	44 g	1.2%n~3HUFA	Lee S M *et al*. [11]
EPA、DHA	2.1 g	均为 1.0%，DHA 优于 EPA，EPA/DHA < 1 足够	Lee S M *et al*. [12]
n-3HUFA	5.9 g	0.9%	Lee S M *et al*. [13]
	6.2 g	1.2% (8%脂肪)达到最高	Lee S M *et al*. [14]
	6.2 g	影响肝细胞膜的完整性	Lee S M *et al*. [15]
	6.2 g	等量非极性脂肪被用作能量消耗	Lee S M *et al*. [16]
类胡萝卜素 carotenoid	49 g	*β*-胡萝卜素、虾青素、叶黄素、角黄素为主	Ha B S *et al*. [17]
维生素 C Vitamin C	3.1 g	106 mg/kg diet	Wang X J *et al*. [18]
	3.1 g	维 C-2-葡萄糖可作为饲料维生素来源	Wang X J *et al*. [19]
	12.6 g	40~150 mg/kg	Bai S C. *et al*. [20]
维生素 E Vitamin E	12.3 g	45 mg/kg diet	Bai S C. *et al*. [21]
维生素预混料 vitamins premix	4.25 g	C 2666，E 417，硫胺素 60，核黄素 200，烟酸 800，吡哆醇 40，泛酸 280，肌醇 4000，生物素 6，叶酸 15，氨基苯甲酸 400，K40，A16，D3 0.1，氯化胆碱 8000。B12 0.09 (mg/kg 饲料)	Lee S M *et al*. [22]
磷 P	4.2 g	0.3%	Lee S M *et al*. [23]
矿物元素 minerals	4.2 g	P、Ca、Zn、Mg、Fe、K、Mn、Se 是许氏平鲉正常生长所必须的矿物元素	Lee S M *et al*. [24]
	9 g	螯合矿物元素比无机矿物元素更高效	Katya K *et al*. [25]
铜 Cu	26.02	500 mg/kg，60 d 可引起肝组织坏死	Kim J W *et al*. [26]
	29.76 g	GSH 是铜毒性的敏感指标，铜毒性与水温相关密切	Min E Y *et al*. [27]
	26.02	抑制生长，血比容、血红蛋白、红细胞、总蛋白、葡萄糖、血钙含量无影响	Kan J C *et al*. [28]
	26.02	蓄积：肝脏 > 肠道 > 肾脏 > 鳃 > 肌肉；排放：肠道 > 肝脏 > 鳃	Kim S G *et al*. [29]
镉 Cd	24.66 g	0.5 $mgkg^{-1}$ 显著抑制生长，降低血相	Kim S G *et al*. [30]

Continued

	24.66	抑制生长，降低血比容及血红蛋白数量，提高血液葡萄糖、总蛋白及镁含量，对血镉含量无影响	Kan J C *et al*. [28]
壬基酚 nonylphenol	50 g	显著提高了转氨酶活力	Hwang U G *et al*. [31]
	-	抑制了视网膜结合蛋白和卵黄蛋白原 MRNA 的表达	Cho H K *et al*. [32]
二甲苯 dimethylbenzanthr-acene	52.5 g	2.4~4.8 mg/kg 暴露 8 周，抑制生长、贫血、降低血相、影响血浆电解质平衡	Jee J H *et al*. [33]
氯氰菊酯 cypermethrin	52.5 g	降低红细胞数量、血比容及血红蛋白含量，提高 AST、ALT、AKP，降低血清总蛋白、白蛋白、胆固醇、胆红素、MDA 含量	Jee J H *et al*. [34]

且螯合矿物元素的效价优于无机矿物元素[25]。此外，还有研究报道了 Cu、Cd、壬基酚、二甲苯、氯氰菊酯对其的胁迫作用[26]-[34]。

3. 许氏平鲉饲料开发

饲料原料及功能性饲料添加剂是优质高效配合饲料的重要组成部分。由表 2 可见，许氏平鲉对白鱼粉、鳀鱼粉、肉粉、玉米蛋白粉的表观消化率均较高[35] [36]，不同种类的鱼粉均是适宜于许氏平鲉的优质蛋白原料[37]，鱼皮粉、DDGs、豆粕、肉骨粉等可替代饲料中的部分鱼粉[38]-[45]。补充晶体氨基酸后，豆粕可以更高比例的替代鱼粉[41]。复合蛋白源可替代更多鱼粉[42] [44]。α 马铃薯淀粉更适宜作为饲料能量来源[46]。在功能性饲料添加剂方面，研究表明：姜黄素、绿茶提取物、雪莲、蓝莓、羊栖菜、韭葱、蒲公英、枸杞、益生菌、中草药、类胰岛素生长因子、β-葡聚糖、海芥菜、芦荟等对许氏平鲉具有不同的生理作用，这与添加剂的活性成分有关[47]-[58]。饲料中添加微生物植酸酶能提高 P 的利用率[59]。

由表 3 可见，干颗粒饲料的使用效果与冰鲜鱼、湿颗粒饲料差异不显著，且颗粒饲料易保存运输、使用方便、营养全面、物质转化率高，可以应用于许氏平鲉的全程养殖中[60] [61] [62] [63]。随着许氏平鲉体重的增加，日投喂次数和投喂量逐渐减少，由仔稚鱼期的日投喂 5~6 次，逐渐降低到幼鱼期的日投喂 1 次或 2 次[64]-[69]。由于许氏平鲉存在自残现象，故日投喂量的控制非常重要。随着体重的增加，日投喂量也在逐渐降低，体重 5 g 时，投喂量为体重的 4%左右，体重 16 克时，投喂量约为体重的 3% [69] [70]。此外，非常重要的是日投喂频率和日投喂量与养殖水温密切相关[64]-[70]。20℃是较为适宜的养殖温度，午夜到黎明是较为适宜的投喂时间[71]；低于 15℃或高于 24℃时，应减少投喂频率和投喂量；低于 4℃或高于 26℃或昼夜温差较大时，应禁止投喂[72] [73]，且应做好增氧增水等防范准备。

4. 许氏平鲉养殖产业存在的问题及未来的发展方向

深远海网箱养殖是《全国渔业发展第十三个五年规划(2016~2020)》中重点提倡的海水养殖方式之一。许氏平鲉是较为适宜深远海网箱养殖的鱼种之一，且在我国有一定的养殖基础。苗种、模式、投入品、运输等是困扰目前许氏平鲉养殖产业发展的主要问题。长期以来，网箱养殖许氏平鲉种苗的来源主要以海捕为主，海捕苗种规格不齐、应激性高、养殖成活率较低，是限制产业发展的最大问题。近年来，许氏平鲉的繁育技术得到突破，可为产业提供部分优质苗种，但目前繁育技术仍存在一定问题，出苗量不能满足产业的需求。目前，我国许氏平鲉的养殖主要集中在山东烟台长岛海域，以深水网箱养殖模式为主；长岛附近海域水质优良，但年养殖适温时间较短，养殖周期较长，增加了养殖成本和养殖风险。如前文所述，目前我国许氏平鲉养殖过程中，尚主要以投喂鲜杂鱼为主，鲜杂鱼的投喂不仅不符合国家产业和环保政策，而且增加了疾病传播的风险；此外随着产业的发展，投入品的需求量会越来越大，仅仅依靠冰鲜鱼难以满足产业发展需求。许氏平鲉的鳍条非常坚硬，受到应激后迅速伸张，极易造成互相伤

Table 2. Raw materials and feed additives for Korean rockfish *Sebastes schlegeli*
表 2. 饲料原料及功能性饲料添加剂

指标 indices	鱼体重 body weight	结果 results	文献来源 references
表观消化率 apparent digestibility coefficients	30 g, 300 g	白鱼粉、鲽鱼粉、肉粉、玉米蛋白粉的蛋白质表观消化率较高	Lee S M *et al*. [35]
	3.1 g	许氏平鲉肌肉粉蛋白质及磷的表观消化率最高，白鱼粉的表观消化率也较高，玉米蛋白粉及豆粕中磷的表观消化率较低	Bai S C *et al*. [36]
鱼粉 fishmeal	5.7 g	蒸汽白鱼粉的增重及饲料效率优于褐鱼粉，但对摄食率、蛋白质及脂肪存留率无影响	Lee S M *et al*. [37]
	86.6 g	蒸汽白鱼粉、直火白鱼粉、褐鱼粉、鱼粉蛋白水解物之间无差异	Lee S M *et al*. [37]
原料 raw materials	10.05 g	鲆鲽鱼皮粉替代酪蛋白，促生长、降体脂，提高 HDL-C 和 TP，降血脂，提高抗应激能力。	Hwang J H *et al*. [38]
	68.0 g	蒸馏谷物可以替代饲料中 14%以上的面粉	Choi J *et al*. [39]
	10.2 g	蒸馏谷物替代鱼粉抑制生长	Bae K M *et al*. [40]
	2.5 g, 21.5 g	不补充氨基酸时，去皮豆粕替代 20%鱼粉；补充氨基酸，替代 30%鱼粉	Lim S R *et al*. [41]
	22.9 g	豆粕可替代 20%白鱼粉，复合蛋白源可替代更多鱼粉	Lee S M *et al*. [42]
	7.75 g	禽副产物粉、肉骨粉、豆粕、棉籽粕可替代饲料中 15%的鱼粉蛋白	Yan Q G *et al*. [43]
	114 g	配合饲料中 50%以上的鱼粉可被动植物蛋白替代，添加氨基酸和酶复合物对鱼无影响	Lee S M *et al*. [44]
	4.1 g	饲料中肉粉用量可在 10%~20%之间。	Lee Y W *et al*. [45]
	30 g	α 马铃薯淀粉更适合作为许氏平鲉饲料糖能量	Lee S M *et al*. [46]
添加剂 additives	10.05 g	姜黄素降脂提高蛋白，提高油酸和 EPA 含量	Hwang J H *et al*. [47]
	8.1 g	绿茶提取物提高脂肪利用、溶菌酶活力、抗应激能力，降低总胆固醇	Hwang J H *et al*. [48]
	4.3 g	雪莲和蓝莓促生长，姜黄素提高蛋白质效率	Lee K W *et al*. [49]
	4.2 g	羊栖菜、韭葱、蒲公英对生长及饲料利用无影响，但能提高免疫保护率	Yun A *et al*. [50]
	3.36 g	适量添加枸杞可促进生长，提高非特异性免疫和疾病抵抗能力	Lim D K *et al*. [51]
	12.0 g	益生菌促生长、提高免疫和疾病抵抗力	Lee S *et al*. [52]
	0.7 g	10^8 cfu/g 乳酸菌可促生长	Park S H *et al*. [53]
	47 g	类胰岛素生长因子对许氏平鲉有生物作用，可促生长	Nam T J *et al*. [54]
	3.6 g, 166 g	中草药提高饲料效率和蛋白质效率	Seo J Y *et al*. [55]
	4.0 g	0.05% β~1.3 葡聚糖，提高蛋白质效率和增重	Kim Y C *et al*. [56]
	1.03~120.64 g	5%海芥菜可促生长、增加红细胞数量，提高耐低氧能力	Yi Y H *et al*. [57]
	25 g	0.5%芦荟可提高抗溶藻弧菌的免疫保护力	Kim K H *et al*. [58]
	7.25 g	微生物植酸酶提高磷的消化率	Yoo G Y *et al*. [59]

Table 3. Feeding husbandry for Korean rockfish *Sebastes schlegeli*
表 3. 许氏平鲉配合饲料投喂策略

指标 indices	鱼体重 body weight	结果 results	文献来源 references
不同颗粒 particles	68.5 g	三种饲料(冰鲜马鲛鱼；80%冰鲜马鲛鱼+20%粉末饲料；50%冰鲜马鲛鱼+50%粉末饲料)对实验鱼的生长、体成分均无显著影响	Lee J Y *et al*. [60]
	4.7 g	干颗粒、湿颗粒、冰鲜马鲛鱼+粉末饲料对生长及体成分无显著影响	Lee S M *et al*. [61]
	10.9 g	冰鲜马鲛鱼 + 粉末饲料生长效果优于干、湿颗粒	Lee S M *et al*. [61]
	112 g	颗粒饲料完全适合生长期的许氏平鲉	Kim K D *et al*. [62]
	20.2 g, 57.6 g, 96.3 g	以白鱼粉、豆粕、鱼粉类似物为主要蛋白源的颗粒饲料更适宜于许氏平鲉的全程养殖	Kim K W *et al*. [63]
投喂频率 feeding frequency	5.7 g	1 天投喂 1 次比 1 天投喂 2 次或 2 天投喂 1 次更有效率，干湿颗粒对增重无影响	Lee S M *et al*. [64]
	25 g	1 天投喂 1 次或 2 天投喂 1 次比 1 天投喂 2 次更有效	Lee S M *et al*. [65]
	2.1 g	水温 17.5℃，日投喂 5 次；水温 20℃，日投喂 6 次	Lee J H *et al*. [66]
	2.07 g	水温 15℃，日投喂 2~3 次，日投喂量为体重的 2.9%	Lee J H *et al*. [67]
	5.63 g	日投喂 2 次	冒树泉等 [68]
	93~133 g; 100~132 g	日投喂一次	Mizanur R M *et al*. [69]
投喂量 feeding amount	16 g	20℃优于 16℃和 24℃，投喂量 3.1%~3.7%BW/d	Mizanur R M *et al*. [70]
	5 g	17℃时，投喂量 4.48%；20℃时，投喂量 4.83%	Mizanur R M *et al*. [69]
	16 g	16℃时，投喂量 3.14%；20℃时，投喂量 3.75%；24℃时，投喂量 3.34%	Mizanur R M *et al*. [69]
投喂时间 feeding time	65.3 g	午夜到黎明是投喂的最佳时刻	Park C W *et al*. [71]

害，引起继发性感染死亡，增加了活鱼运输的难度。

因此，在产业的未来发展中，首先应继续研究提高许氏平鲉的繁育技术，为产业提供充足优质健康苗种。其次，应对许氏平鲉的种质进行优化，如增加许氏平鲉的抗高温或温差品性[72] [73]。针对许氏平鲉特殊的生物节律，可适当发展接力养殖模式，即在海域水温不适宜的条件下，进行陆上养殖，海域水温合适时，进行海域养殖；或者在陆上进行保苗，待规格较大时进行海上网箱养殖；此外，许氏平鲉还适宜于海参的混养[74]，适宜于发展生态养殖模式。投入品是养殖产业发展的重要保障，优质的投入品不仅可提高资源的循环利用效率，而且可以提高养殖产业的工业化水平，降低养殖成本，提高养殖效益；此外，发展许氏平鲉的自动投喂装置也势在必行。针对许氏平鲉活鱼运输较为困难的问题，可着重研究不同麻醉剂、不同运输方式及不同运输装置对运输成功率的影响，或者发展许氏平鲉的深加工产业。

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