读书报告

Reading report

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题目
topic

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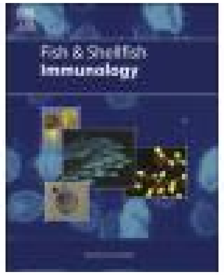

Full length article

Sodium butyrate improved intestinal immune function associated with NF-κB and p38MAPK signalling pathways in young grass carp (*Ctenopharyngodon idella*)

Li Tian [a, 1], Xiao-Qiu Zhou [a, b, c, 1], Wei-Dan Jiang [a, b, c], Yang Liu [a, b, c], Pei Wu [a, b, c], Jun Jiang [a, b, c], Sheng-Yao Kuang [d], Ling Tang [d], Wu-Neng Tang [d], Yong-An Zhang [e], Fei Xie [f], Lin Feng [a, b, c, *]

丁酸钠通过NF-kB和p38MAPK信号传导改善幼龄草鱼的肠道免疫功能

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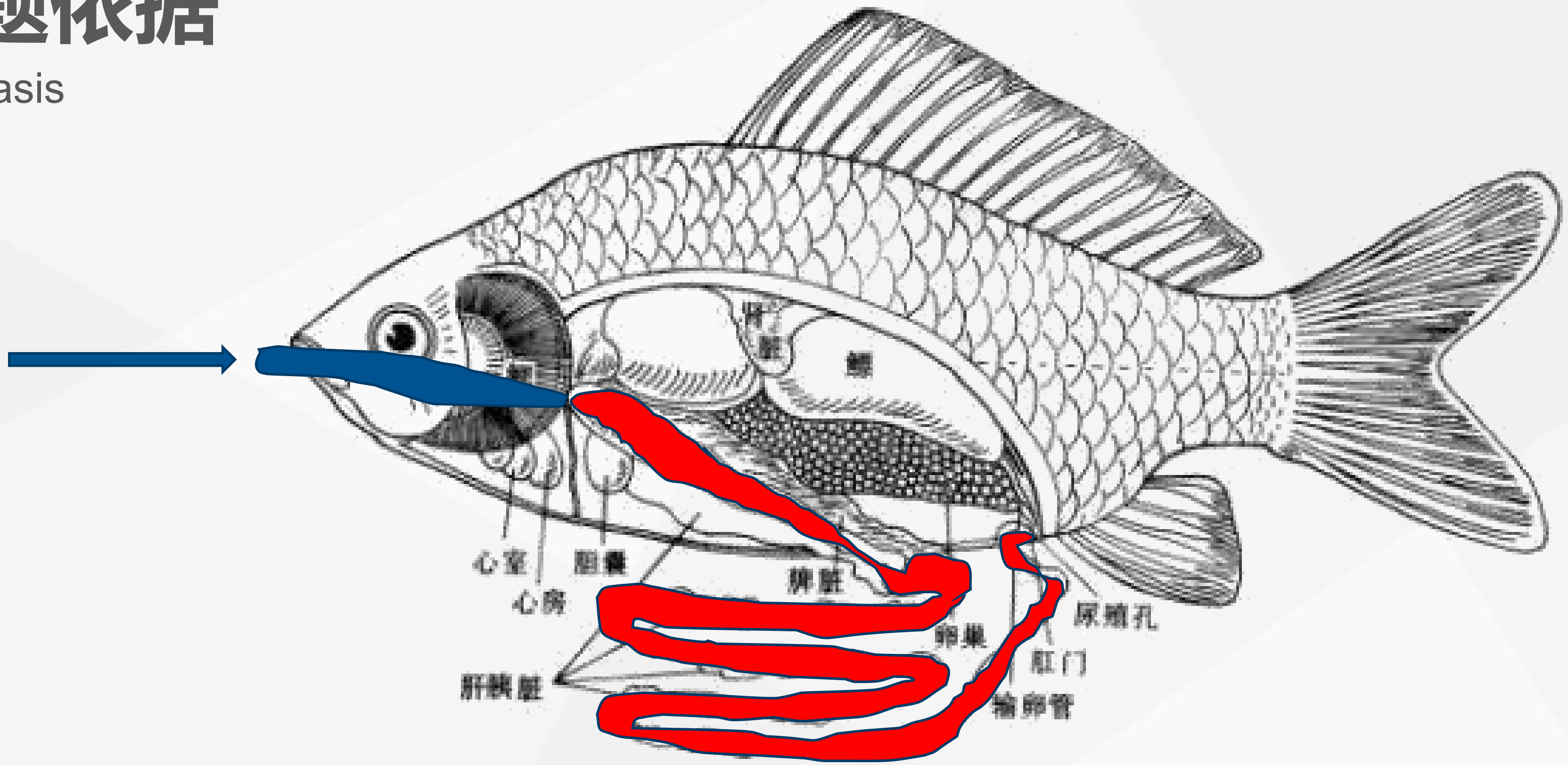


鲤鱼的肠道不断暴露于食物中可能存在的病原体以及外来的寄生虫中，导致疾病的发生，肠道结构的完整性在维持鲤鱼肠道健康方面起着举足轻重的作用。

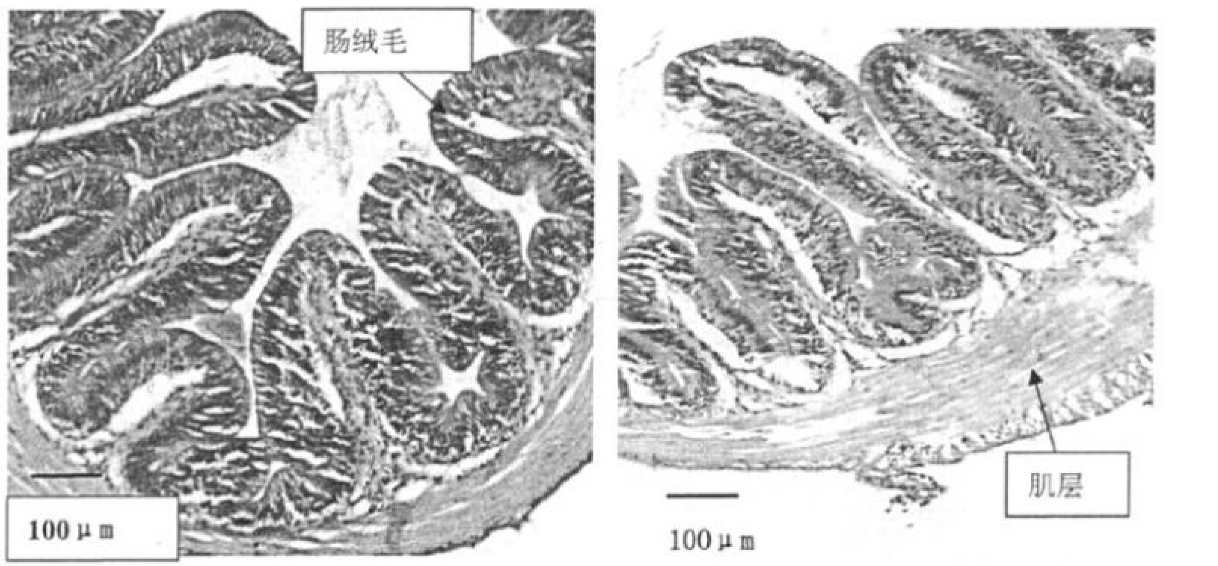
同时鲤鱼体内正常的肠道微生物在维持肠道健康、抵抗病原入侵、调节机体能量吸收和免疫调节过程中均发挥重要作用（song et al., 2007）。

01 背景介绍

01 Background

丁酸钠（SB）可以为肠道细胞提供能量，常被用作饲料添加剂来维持鱼类和陆生动物的肠道健康。研究发现丁酸盐可以抑制瘦素基因的表达，而瘦素水平的降低可以降低小鼠乳腺肿瘤细胞系中的NF-kB表达并抑制人B细胞中的p38MAPK磷酸化。

图版 I：肠绒毛结构比较



1、 对照组　　2 、500g·t⁻¹ 丁酸…

表 8 丁酸钠对鲤鱼鱼种肠黏膜形态的影响

项目	丁酸钠添加量($g \cdot t^{-1}$)			
	对照组	500	1000	1500
绒毛高度（μm）	627.89±36.52 ^{a}	657.11±41.76 ^{b}	683.67±20.10 ^{c}	765.44±102.04^{E}
绒毛宽度（μm）	110.97±18.86^{a}	128.68±5.64^{bd}	136.66±12.48^{cd}	153.39±11.40^{e}
肌层厚度（μm）	135.40±13.26^{a}	147.30±14.35^{B}	164.51±15.36^{C}	168.40±16.93^{C}

注：同一行数据肩注字母相同者差异不显著(P>0.05)，字母不同者差异显著（P<0.05）

01 背景介绍

01 Background

核因子NF-kB是信号转导过程下游的核转录因子，其通过影响细胞因子网络中多种细胞因子(TNF-α、TNF—β、 IL-6、IL-8、ICAM-1、VCAM-1)基因的转录而对该网络产生广泛的影响。

P38MAPK是近年来发现分裂原激活蛋白激酶(MAPK)的一种亚型，p38丝裂原活化蛋白激酶(p38MAPK) 与应激相关，并具有细胞特异性,在不同细胞作用并不相同,甚至起了完全相反的作用。一些能够激活JNK的促炎因子(TNFα、IL-1)、应激刺激(UV、H2O2、热休克、高渗与蛋白合成抑制剂)也可激活p38。

PART 02

材料和方法

Materials and methods

02 材料和方法

02 Materials and methods

1. 饲料制备

豆粕，棉籽粕，菜籽粕作为膳食蛋白质来源。鱼油和豆油作为脂质来源。最终的SB添加量为每千克饲料中分别添加1000.0,(PSB,98%SB)0.0,500.0,1000.0，1500.0， 2000.0 mg/kg(MSB,30%SB)。在-20℃下保存。

Table 1

Composition and nutrients content of the basal diet.

Ingredients	g kg^{-1}	Nutrients content	g kg^{-1}
Fish meal	30.0	Crude protein[d]	304.6
Soybean meal	213.0	Crude lipid[d]	52.9
Cottonseed meal	120.0	n-3[e]	10.4
Rapeseed meal	100.0	n-6[e]	9.6
Rice gluten meal	140.0	Available phosphorus[f]	4.0
Threonine (98.5%)	0.9		
DL-Methionine (99%)	5.0		
Tryptophan (99%)	0.2		
Maize starch	12.8		
α-starch	280.0		
$Ca(H_2PO_4)_2$	13.9		
Fish oil	29.2		
Soybean oil	4.5		
Vitamin premix[a]	10.0		
Mineral premix[b]	20.0		
Sodium butyrate premix[c]	10.0		
Choline chloride (50%)	10.0		
Ethoxyquin (30%)	0.5		

02 材料和方法

02 Materials and methods

2.养殖管理：

实验对象：草鱼（256.57±0.71g）

实验分组：6个实验组，每组3个重复，每个重复30尾鱼。

投喂时间：每天四次饱食投喂，喂食30分钟后，收集饲料残渣，干燥并称重以计算采食量。

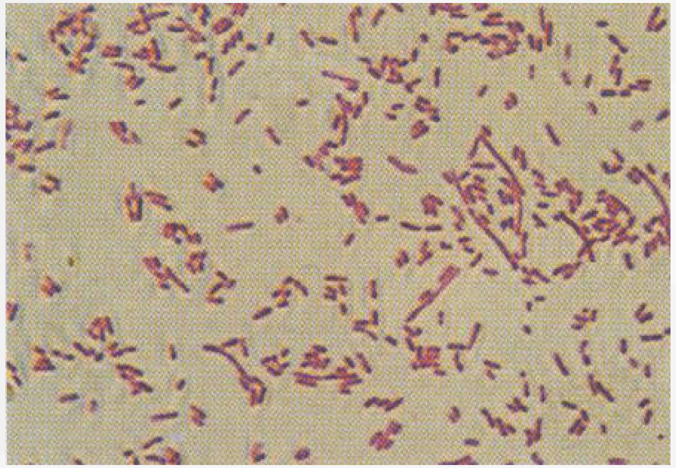
养殖时间：养殖60天。

光照周期：自然光周期。

在试验结束，称重，麻醉，取肠道（胰蛋白酶，糜蛋白酶，脂肪酶，淀粉酶活性以及绒毛长度）与肠道内容物（菌群计数和SCFAs检测），液氮速冻，冻存于-80℃。

02 材料和方法

02 Materials and methods



3.攻毒实验：

每个实验组随机选取15条鱼，暂养为5天后腹腔注射1.0ml2.5x10^9cfu/ml嗜水性气单胞菌（非致死剂量，可以有效地诱导炎症）。实验进行14天。试验期间，实验条件和管理与养殖实验相同。实验结束后，评定鱼肠炎程度，取肠道（LZ、ACP活性，补体C3，C4和IgM含量和基因表达量）液氮速冻并保存在-80℃。

02 材料和方法

02 Materials and methods

4.荧光实时定量PCR

β-actin为内参，基因标准曲线由连续10倍稀释。

Table 2
Real-time PCR primer sequences.[a]

Target gene	Primer sequence Forward (5′→3′)	Primer sequence Reverse (5′→3′)	Temperature (°C)	Accession number
β-defensin-1	TTGCTTGTCCTTGCCGTCT	AATCCTTTGCCACAGCCTAA	58.4	KT445868
hepcidin	AGCAGGAGCAGGATGAGC	GCCAGGGGATTTGTTTGT	59.3	JQ246442.1
LEAP-2A	TGCCTACTGCCAGAACCA	AATCGGTTGGCTGTAGGA	59.3	FJ390414
LEAP-2B	TGTGCCATTAGCGACTTCTGAG	ATGATTCGCCACAAAGGGG	59.3	KT625603
Mucin2	GAGTTCCCAACCCAACACAT	AAAGGTCTACACAATCTGCCC	60.4	KT625602
TNF-α	CGCTGCTGTCTGCTTCAC	CCTGGTCCTGGTTCACTC	58.4	HQ696609
IFN-γ2	TGTTTGATGACTTTGGGATG	TCAGGACCCGCAGGAAGAC	60.4	JX657682
IL-1β	AGAGTTTGGTGAAGAAGAGG	TTATTGTGGTTACGCTGGA	57.1	JQ692172
IL-6	CAGCAGAATGGGGGAGTTATC	CTCGCAGAGTCTTGACATCCTT	62.3	KC535507.1
IL-8	ATGAGTCTTAGAGGTCTGGGT	ACAGTGAGGGCTAGGAGGG	60.3	JN663841
IL-15	CCTTCCAACAATCTCGCTTC	AACACATCTTCCAGTTCTCCTT	61.4	KT445872
IL-17D	GTGTCCAGGAGAGCACCAAG	GCGAGAGGCTGAGGAAGTTT	62.3	KF245426.1
IL-12p35	TGGAAAAGGAGGGGAAGATG	AGACGGACGCTGTGTGAGTGTA	55.4	KF944667.1
IL-12p40	ACAAAGATGAAAAACTGGAGGC	GTGTGTGGTTTAGGTAGGAGCC	59.0	KF944668.1
IL-10	AATCCCTTTGATTTTGCC	GTGCCTTATCCTACAGTATGTG	61.4	HQ388294
IL-11	GGTTCAAGTCTCTTCCAGCGAT	TGCGTGTTATTTTGTTCAGCCA	57.0	KT445870
TGF-β1	TTGGGACTTGTGCTCTAT	AGTTCTGCTGGGATGTTT	55.9	EU099588
TGF-β2	TACATTGACAGCAAGGTGGTG	TCTTGTTGGGGATGATGTAGTT	55.9	KM279716
IL-4/13A	CTACTGCTCGCTTTCGCTGT	CCCAGTTTTCAGTTCTCTCAGG	55.9	KT445871
IL-4/13B	TGTGAACCAGACCCTACATAACC	TTCAGGACCTTTGCTGCTTG	55.9	KT625600
NF-κB p52	TCAGTGTAACGACAACGGGAT	ATACTTCAGCCACACCTCTCTTAG	58.4	KM279720
NF-κB p65	GAAGAAGGATGTGGGAGATG	TGTTGTCGTAGATGGGCTGAG	62.3	KJ526214
c-Rel	GCGTCTATGCTTCCAGATTTACC	ACTGCCACTGTTCTTGTTCACC	59.3	KT445865
IκBα	TCTTGCCATTATTCACGAGG	TGTTACCACAGTCATCCACCA	62.3	KJ125069
IKKα	GGCTACGCCAAAGACCTG	CGGACCTCGCCATTCATA	60.3	KM279718
IKKβ	GTGGCGGTGGATTATTGG	GCACGGGTTGCCAGTTTG	60.3	KP125491
IKKγ	AGAGGCTCGTCATAGTGG	CTGTGATTGGCTTGCTTT	58.4	KM079079
p38MAPK	TGGGAGCAGACCTCAACAAT	TACCATCGGGTGGCAACATA	60.4	KM112098
MAPKK6	GAGCATCTCCACAGCAACCT	CTTCGCCACTGAATCCACAA	57.1	KT445869
β-actin	GGCTGTGCTGTCCCTGTA	GGGCATAACCCTCGTAGAT	61.4	M25013

[a] LEAP-2, liver expressed antimicrobial peptide 2; TNF-α, tumor necrosis factor α; IFN-γ2, interferon γ2; IL, interleukin; TGF-β, transforming growth factor β; NF-κB, nuclear factor kappa B; IκBα, inhibitor of κBα; IKK, IκB kinase; p38MAPK, p38 mitogen-activated protein kinase; MAPKK, MAPK kinase.

5.生化分析：

将肠样品在10倍体积的冰冷的生理盐水中匀浆，并在4℃，6000g离心20分钟，然后收集上清液进行胰蛋白酶、糜蛋白酶、脂肪酶和淀粉酶、溶菌酶和酸性磷酸酶活性，C3，C4和IgM的测定。

6.数据分析：

计算PWG，SGR和FE，ISI（肠体比）。

MSB相对于PSB的功效由线性斜率比模型得到。。

$$PWG = 100 \times [FBW\ (g\ fish^{-1}) - IBW\ (g\ fish^{-1})]/IBW\ (g\ fish^{-1});$$
$$FE = 100 \times [FBW\ (g\ fish^{-1}) - IBW\ (g\ fish^{-1})]/FI\ (g\ fish^{-1});$$
$$SGR = 100 \times [\ln\ (\text{final weight}) - \ln\ (\text{initial weight})]/\text{days};$$
$$ISI = 100 \times [\text{wet intestine weight (g)}/\text{wet body weight (g)}].$$

PART 03

结果

Result

03 结果

03 Result

Table 3

Growth performance, intestinal growth, digestive enzymes activities, intestinal bacterial counts, intestinal SCFAs concentrations, and folds height in the proximal intestine (PI), middle intestine (MI) and distal intestine (DI) of young grass carp (*Ctenopharyngodon idella*) fed diets containing 1000.0 mg kg^{-1} powdery sodium butyrate (PSB) and graded levels of microencapsulated sodium butyrate (MSB) (mg kg^{-1} diet) for 60 days.

	PSB (SB)	MSB (SB)				
	1000.0 (590.3)	0.0 (control)	500.0 (160.8)	1000.0 (326.8)	1500.0 (424.2)	2000.0 (593.8)
IBW[A]	256.78 ± 0.69^{a}	256.22 ± 0.77^{a}	256.78 ± 0.96^{a}	256.44 ± 0.38^{a}	256.11 ± 0.96^{a}	257.11 ± 0.38^{a}
FBW[A]	688.00 ± 9.17^{d}	617.11 ± 5.05^{a}	781.56 ± 6.71^{f}	719.08 ± 5.24^{e}	661.48 ± 8.84^{c}	633.17 ± 8.19^{b}
PWG[A]	167.94 ± 2.88^{d}	140.85 ± 1.26^{a}	204.37 ± 3.70^{f}	180.40 ± 1.67^{e}	158.28 ± 2.66^{c}	146.26 ± 3.10^{b}
SGR[A]	1.64 ± 0.02^{d}	1.46 ± 0.01^{a}	1.86 ± 0.02^{f}	1.72 ± 0.01^{e}	1.58 ± 0.02^{c}	1.50 ± 0.02^{b}
FI[A]	760.46 ± 0.26^{d}	693.87 ± 0.82^{a}	837.48 ± 4.27^{f}	795.53 ± 2.91^{e}	746.06 ± 0.81^{c}	714.20 ± 1.13^{b}
FE[A]	56.71 ± 1.10^{c}	52.01 ± 0.56^{a}	62.66 ± 0.64^{d}	58.16 ± 0.68^{c}	54.34 ± 1.09^{b}	52.65 ± 1.15^{a}
IL[B]	61.34 ± 4.18^{bc}	56.22 ± 2.86^{a}	65.22 ± 3.67^{d}	64.10 ± 4.75^{cd}	62.33 ± 1.20^{bc}	59.95 ± 0.67^{b}
IW[B]	16.00 ± 0.62^{c}	11.98 ± 0.98^{a}	19.30 ± 0.99^{e}	17.53 ± 1.11^{d}	14.77 ± 0.78^{b}	12.73 ± 1.11^{a}
ISI[B]	2.36 ± 0.24^{bc}	2.04 ± 0.16^{a}	2.54 ± 0.20^{d}	2.45 ± 0.18^{cd}	2.28 ± 0.16^{b}	2.06 ± 0.19^{a}
Trypsin[C]	1.43 ± 0.06^{cd}	1.11 ± 0.05^{a}	1.36 ± 0.04^{c}	1.51 ± 0.08^{d}	1.25 ± 0.05^{b}	1.11 ± 0.07^{a}
Chymotrypsin[C]	1.38 ± 0.09^{c}	1.07 ± 0.04^{a}	1.41 ± 0.12^{c}	1.35 ± 0.08^{bc}	1.26 ± 0.05^{b}	1.09 ± 0.06^{a}
Lipase[C]	1278.82 ± 155.65^{b}	805.19 ± 116.02^{a}	1610.37 ± 232.03^{c}	1752.46 ± 213.93^{c}	1231.46 ± 146.75^{b}	757.82 ± 146.75^{a}
Amylase[C]	947.61 ± 65.19^{c}	761.19 ± 41.29^{a}	915.28 ± 65.27^{bc}	1042.34 ± 31.79^{d}	866.46 ± 47.25^{b}	728.64 ± 40.24^{a}
Aeromonas[C]	6.75 ± 0.10^{b}	7.31 ± 0.10^{c}	6.21 ± 0.36^{a}	6.52 ± 0.00^{ab}	6.62 ± 0.13^{ab}	6.64 ± 0.36^{b}
E. coli[C]	7.34 ± 0.14^{ab}	7.97 ± 0.02^{c}	7.32 ± 0.17^{ab}	7.13 ± 0.29^{a}	7.45 ± 0.30^{ab}	7.70 ± 0.23^{bc}
lactobacillus[C]	7.71 ± 0.07^{bc}	6.83 ± 0.14^{a}	7.71 ± 0.24^{bc}	7.95 ± 0.23^{c}	7.41 ± 0.33^{b}	7.37 ± 0.19^{b}
Acetate[C]	2.26 ± 0.15^{a}	5.41 ± 0.36^{d}	3.07 ± 0.20^{b}	4.47 ± 0.36^{c}	4.81 ± 0.43^{c}	7.88 ± 0.35^{e}
Propionate[C]	0.39 ± 0.01^{a}	0.95 ± 0.08^{c}	0.41 ± 0.04^{a}	0.37 ± 0.04^{a}	0.67 ± 0.03^{b}	0.68 ± 0.07^{b}
Butyrate[C]	0.94 ± 0.06^{b}	0.48 ± 0.04^{a}	0.99 ± 0.03^{bc}	1.06 ± 0.06^{c}	1.34 ± 0.03^{d}	1.47 ± 0.03^{e}
Folds height[D]						
PI	1052.60 ± 178.93^{a}	996.77 ± 150.91^{a}	1164.39 ± 93.00^{bc}	1212.93 ± 127.18^{c}	1191.28 ± 165.71^{bc}	1096.09 ± 136.23^{ab}
MI	1169.48 ± 149.10^{c}	808.99 ± 134.78^{a}	1050.48 ± 101.94^{b}	1061.28 ± 119.19^{b}	1046.34 ± 116.08^{b}	1037.08 ± 85.92^{b}
DI	680.62 ± 67.90^{b}	534.00 ± 77.55^{a}	821.04 ± 85.79^{d}	746.00 ± 58.00^{c}	723.76 ± 57.68^{bc}	693.66 ± 48.93^{b}

生长性能

酶活性

菌群

SCFAs

绒毛高度

03 结果

03 Result

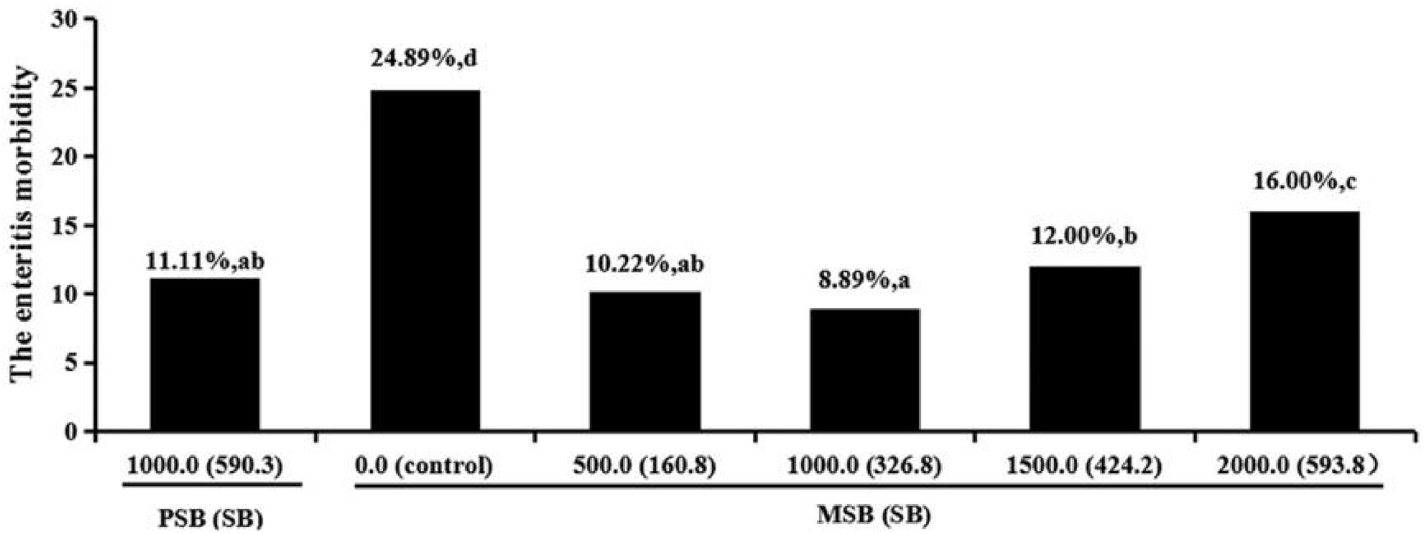


Fig. 1. Effects of dietary SB supplementation (mg kg^{-1} diet) on enteritis morbidity of young grass carp after infection of *Aeromonas hydrophila*. Values having different letters are significantly different ($P < 0.05$).

Fig. 2. Compared with control diet, PSB and optimal MSB supplementation alleviated enteritis symptom after challenged with *A. hydrophila* in young grass carp.

03 结果

03 Result

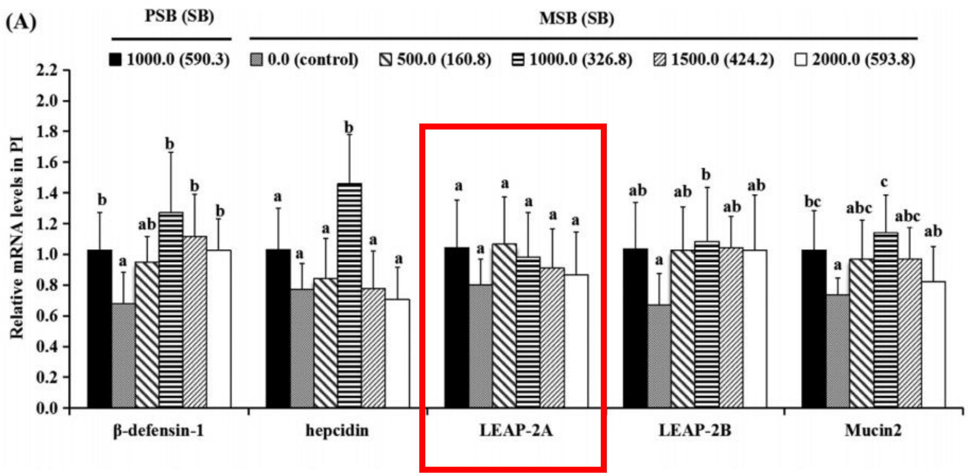
Table 4
LZ and ACP activities (U mg^{-1} protein), C3, C4 and IgM contents (mg g^{-1} protein) in the PI, MI and DI of young grass carp fed diets containing 1000.0 mg kg^{-1} PSB and graded levels of MSB (mg kg^{-1}diet).[A]

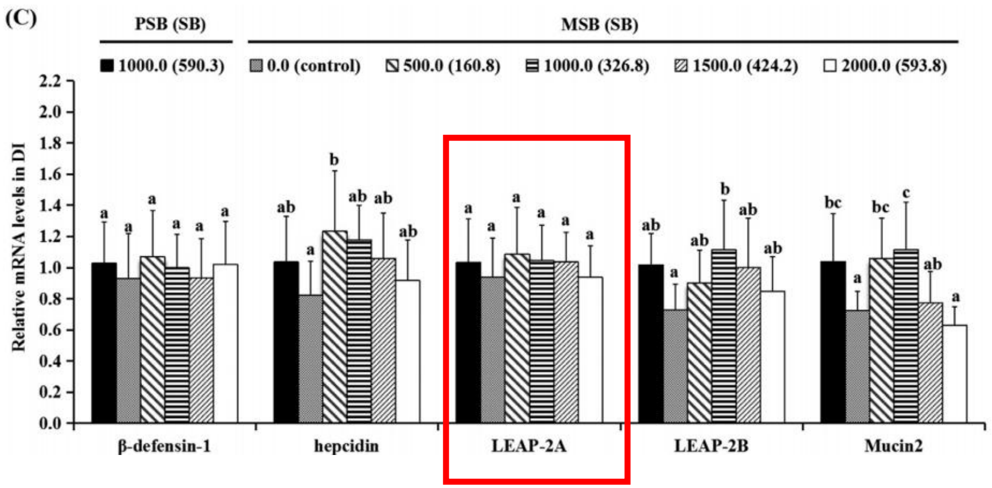
	PSB (SB)	MSB (SB)				
	1000.0 (590.3)	0.0 (control)	500.0 (160.8)	1000.0 (326.8)	1500.0 (424.2)	2000.0 (593.8)
PI						
LZ	124.47 ± 10.05^{cd}	91.42 ± 6.89^{a}	124.86 ± 7.55^{cd}	131.69 ± 11.21^{d}	116.13 ± 13.29^{bc}	105.33 ± 16.73^{b}
ACP	313.78 ± 21.85^{c}	218.10 ± 16.50^{a}	317.81 ± 29.11^{c}	319.04 ± 30.77^{c}	309.66 ± 28.96^{c}	256.25 ± 24.13^{b}
C3	23.20 ± 0.84^{d}	18.36 ± 1.43^{a}	22.66 ± 2.17^{cd}	24.04 ± 1.23^{d}	21.13 ± 1.91^{bc}	19.36 ± 0.95^{ab}
C4	11.07 ± 0.78^{d}	5.98 ± 0.51^{a}	9.53 ± 0.62^{c}	11.51 ± 1.08^{d}	8.67 ± 0.47^{b}	6.66 ± 0.58^{a}
IgM	53.48 ± 5.73^{bc}	45.78 ± 3.79^{a}	49.18 ± 3.32^{ab}	54.14 ± 3.40^{bc}	55.06 ± 5.96^{c}	55.11 ± 3.44^{c}
MI						
LZ	127.36 ± 8.33^{cd}	95.50 ± 15.77^{a}	129.11 ± 6.65^{cd}	136.87 ± 9.61^{d}	119.67 ± 7.86^{bc}	112.07 ± 6.14^{b}
ACP	350.98 ± 25.96^{c}	237.71 ± 20.84^{a}	389.67 ± 21.26^{d}	407.66 ± 30.46^{d}	337.02 ± 15.28^{c}	288.41 ± 30.36^{b}
C3	26.11 ± 1.68^{b}	21.82 ± 1.07^{a}	25.93 ± 1.79^{b}	28.51 ± 2.30^{c}	25.27 ± 1.78^{b}	22.43 ± 0.95^{a}
C4	12.49 ± 1.28^{c}	8.77 ± 0.79^{a}	11.66 ± 0.82^{bc}	14.95 ± 1.35^{d}	12.33 ± 1.22^{c}	10.41 ± 0.88^{b}
IgM	65.23 ± 6.47^{c}	55.46 ± 6.71^{a}	58.10 ± 3.24^{ab}	66.18 ± 6.07^{c}	64.23 ± 4.86^{bc}	56.93 ± 5.48^{a}
DI						
LZ	166.31 ± 10.78^{d}	95.87 ± 11.83^{a}	161.37 ± 8.27^{d}	170.53 ± 5.99^{d}	148.83 ± 9.03^{c}	120.57 ± 13.04^{b}
ACP	341.53 ± 20.71^{cd}	246.46 ± 29.05^{a}	366.31 ± 16.07^{d}	412.23 ± 24.50^{e}	334.46 ± 27.93^{c}	300.68 ± 20.39^{b}
C3	35.32 ± 1.31^{bc}	27.08 ± 1.36^{a}	36.99 ± 2.52^{c}	40.59 ± 2.71^{d}	33.17 ± 2.29^{b}	29.07 ± 1.05^{a}
C4	19.09 ± 1.30^{d}	11.81 ± 1.68^{a}	17.14 ± 1.70^{c}	21.08 ± 1.22^{e}	15.88 ± 0.92^{c}	13.55 ± 0.97^{b}
IgM	70.91 ± 6.77^{cd}	62.05 ± 7.82^{ab}	64.74 ± 6.42^{abc}	73.04 ± 4.79^{d}	67.80 ± 5.11^{bcd}	59.63 ± 6.30^{a}

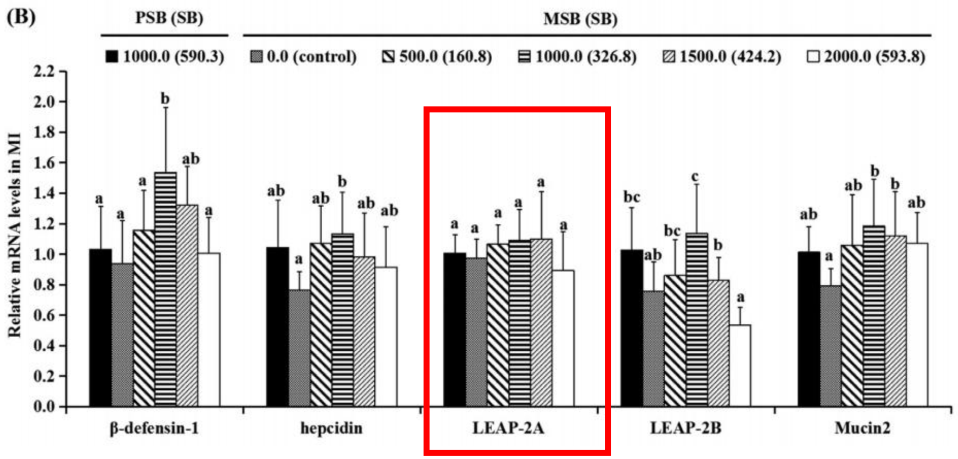
[A] Values are means ± SD (n = 6), and different superscript in the same row are significantly different ($P < 0.05$). LZ, lysozyme; ACP, acid phosphatase; C3, complement 3; IgM, immunoglobulin M.

03 结果

03 Result



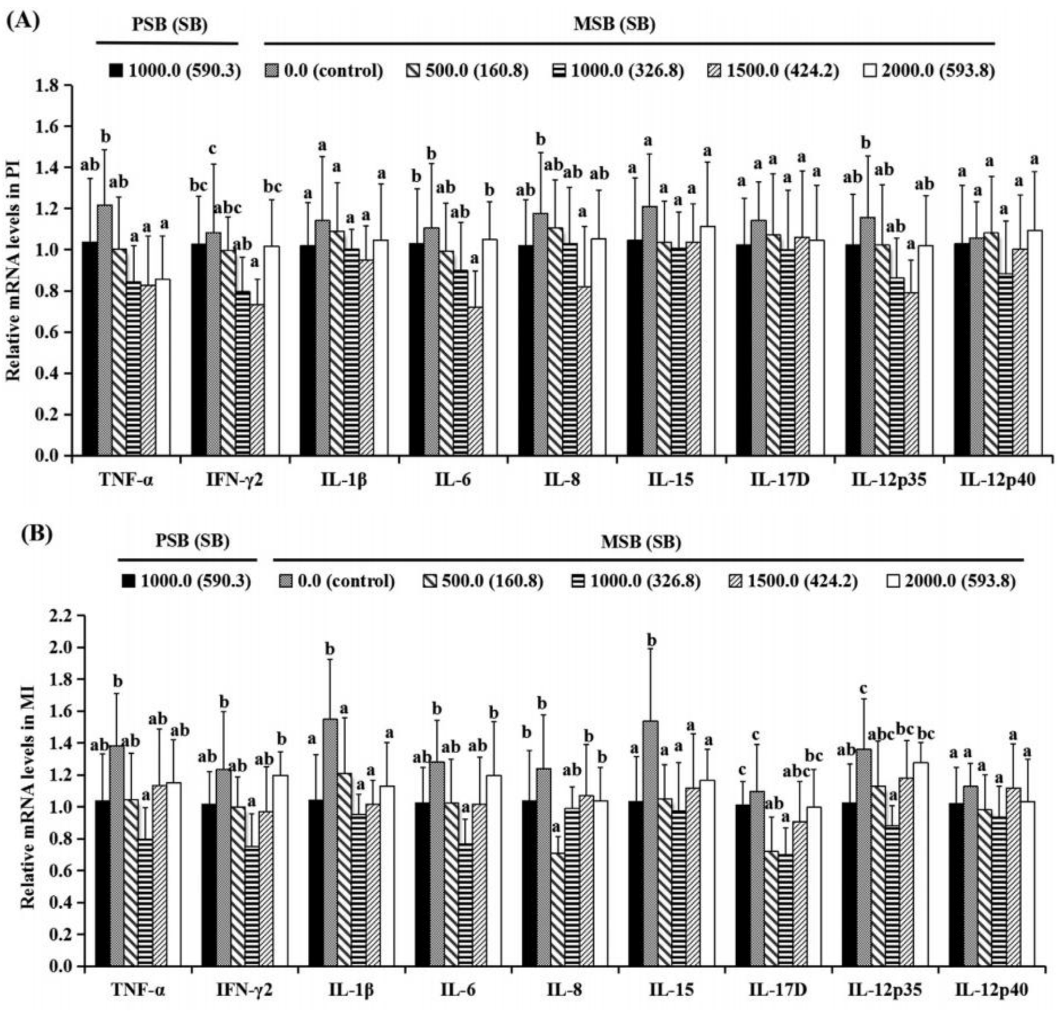


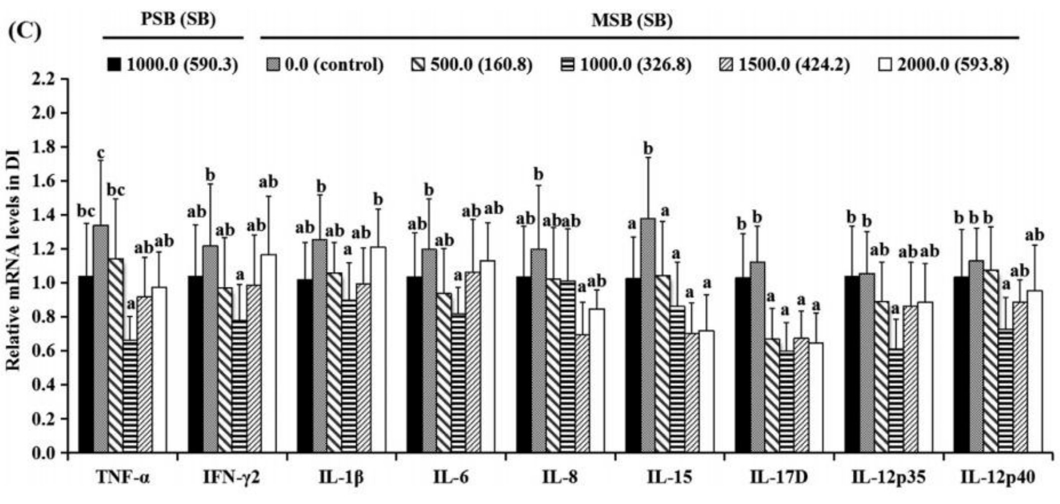


抗菌肽表达量

03 结果

03 Result

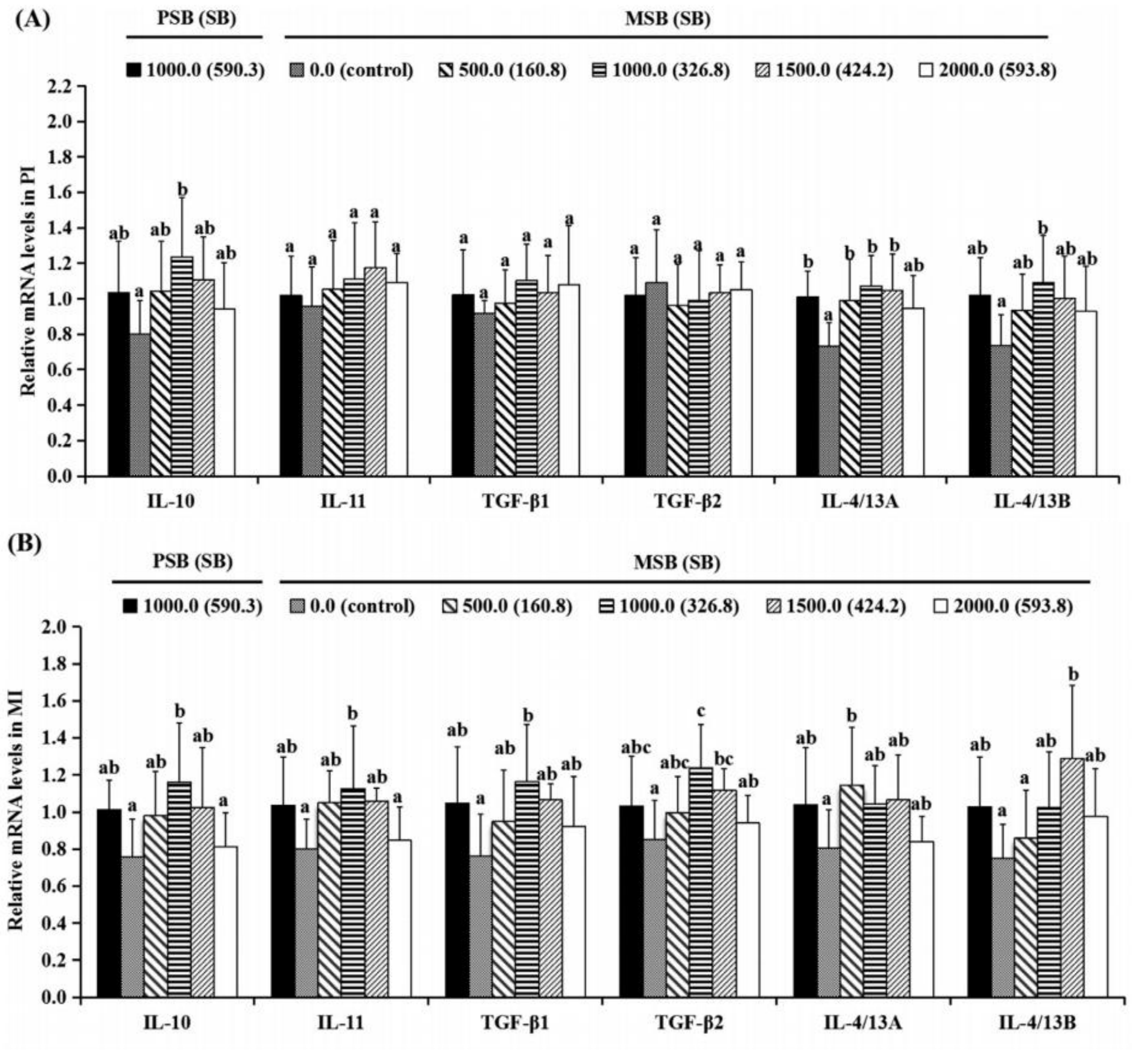


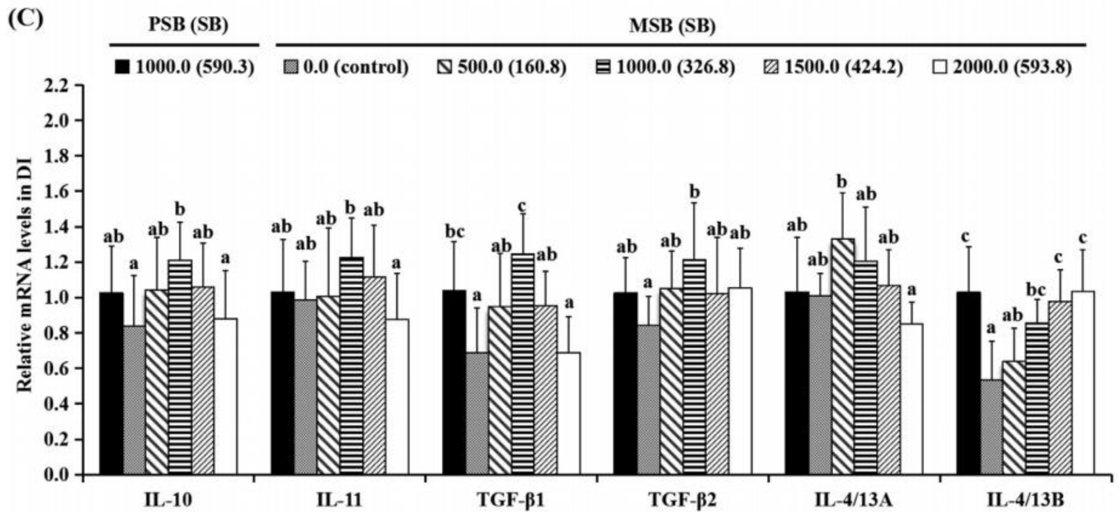


促炎因子表达量

03 结果

03 Result

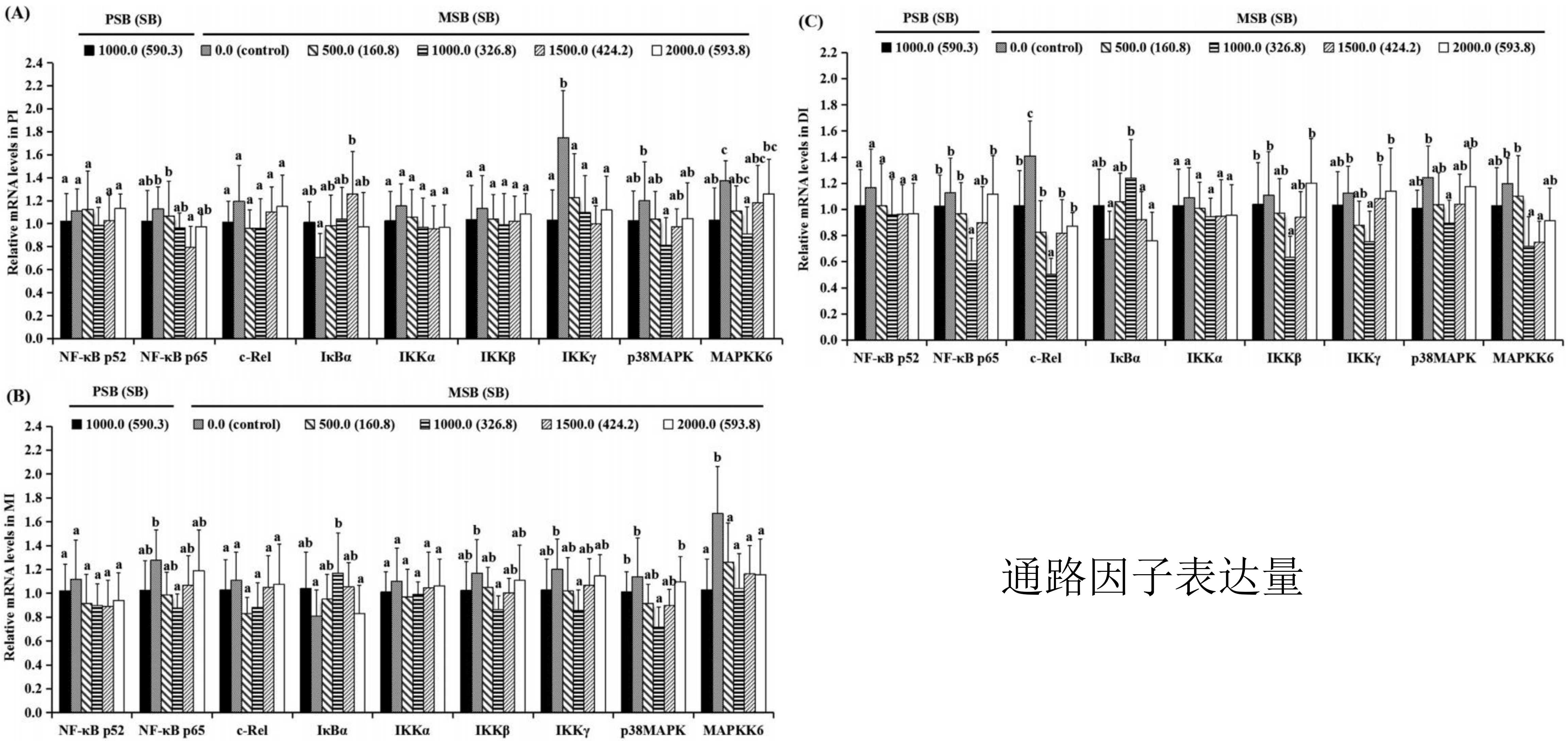




抑炎因子表达量

03 结果

03 Result



通路因子表达量

03 结果

03 Result

促炎、抑炎因子与通路因子之间相关性分析。结果表明：通路因子表达量与促炎因子成正相关，与抑炎因子成负相关。

Table 5
Correlation coefficient of parameters in the intestine.

Dependent parameters	Independent parameters	PI		MI		DI	
		Correlation coefficients	*P*	Correlation coefficients	*P*	Correlation coefficients	*P*
TNF-α	NF-κB p65	+0.825	=0.086	+0.949	<0.05	+0.832	=0.080
	c-Rel	–	–	–	–	+0.916	<0.05
	p38MAPK	+0.810	=0.096	+0.916	<0.05	+0.824	=0.086
IFN-γ2	NF-κB p65	+0.863	=0.059	+0.958	<0.05	+0.968	<0.01
	c-Rel	–	–	–	–	+0.868	=0.056
	p38MAPK	+0.801	=0.104	+0.999	<0.01	+0.996	<0.01
IL-1β	NF-κB p65	–	–	+0.760	=0.136	+0.947	<0.05
	c-Rel	–	–	–	–	+0.857	=0.064
	p38MAPK	–	–	+0.779	=0.121	+0.981	<0.01
IL-6	NF-κB p65	+0.907	<0.05	+0.970	<0.01	+0.897	<0.05
	c-Rel	–	–	–	–	+0.861	=0.061
	p38MAPK	–	–	+0.994	<0.01	+0.954	<0.05
IL-8	NF-κB p65	+0.988	<0.01	–	–	–	–
IL-15	NF-κB p65	–	–	+0.891	<0.05	–	–
	c-Rel	–	–	–	–	+0.740	=0.153
	p38MAPK	–	–	+0.821	=0.088	–	–
IL-17D	NF-κB p65	–	–	+0.971	<0.01	–	–
	c-Rel	–	–	–	–	+0.941	<0.05
	p38MAPK	–	–	+0.887	<0.05	+0.740	=0.153
IL-12p35	NF-κB p65	+0.912	<0.05	+0.961	<0.01	+0.924	<0.05
	c-Rel	–	–	–	–	+0.934	<0.05
	p38MAPK	+0.820	=0.089	+0.967	<0.01	+0.916	<0.05
IL-12p40	NF-κB p65	–	–	–	–	+0.849	=0.069
	c-Rel	–	–	–	–	+0.845	=0.071
	p38MAPK	–	–	–	–	+0.794	=0.109
IL-10	NF-κB p65	–	–	−0.957	<0.05	−0.967	<0.01
	c-Rel	–	–	–	–	−0.866	=0.058
IL-11	NF-κB p65	–	–	−0.955	<0.05	−0.929	<0.05
TGF-β1	NF-κB p65	–	–	−0.875	=0.052	−0.985	<0.01
	c-Rel	–	–	–	–	−0.816	=0.092
TGF-β2	NF-κB p65	–	–	−0.885	<0.05	−0.818	=0.091
	c-Rel	–	–	–	–	−0.980	<0.01
IL-4/13A	NF-κB p65	–	–	−0.837	=0.077	–	–
NF-κB p65	IκBα	−0.935	<0.05	−0.899	<0.05	−0.928	<0.05
c-Rel	IκBα	–	–	–	–	−0.778	=0.121
IκBα	IKKβ	–	–	−0.974	<0.01	−0.941	<0.05
	IKKγ	−0.917	<0.05	−0.917	<0.05	−0.979	<0.01
p38MAPK	MAPKK6	+0.937	<0.05	+0.716	=0.174	+0.713	=0.177

PART 04

讨论

Discussion

04 分析

04 Discussion

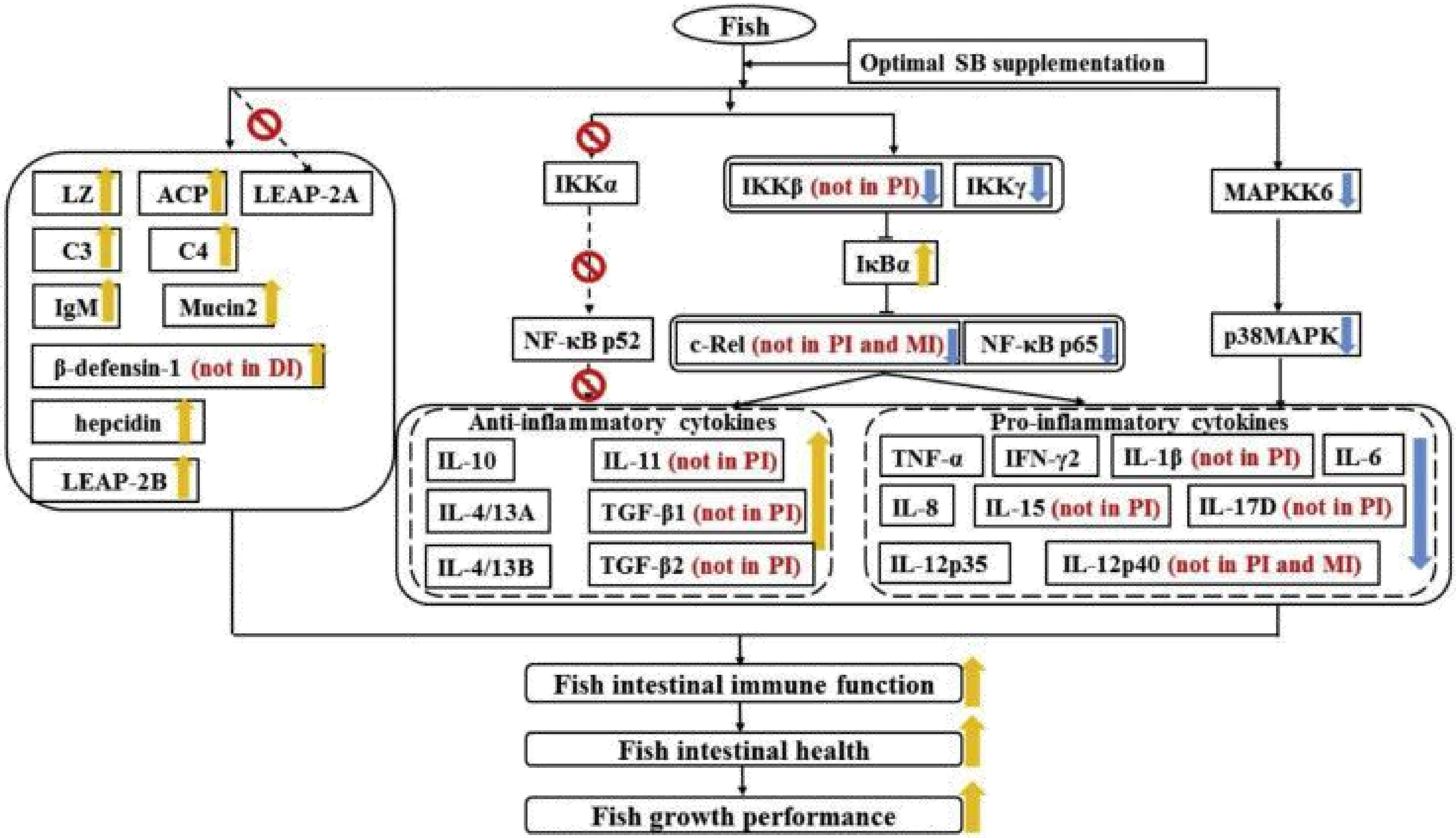


Fig. 7. General summary for the effect of SB on immune function and its potential signalling pathways in the intestine of fish. –⊘ ▸, not through; ——┤, inhibit; ———▶, might through.

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研究表明SB补充提高了鱼的生长性能（PWG，SGR，FI和FE）和肠道IL，IW，ISI，肠绒毛高度，胰蛋白酶，胰凝乳蛋白酶，脂肪酶和淀粉酶活性，增加有益细菌乳酸菌数量，减少气单胞菌和大肠杆菌数量，增加丁酸浓度，并降低了乙酸和丙酸的浓度。

结果表明：

（1）SB添加剂增加草鱼的肠炎抵抗力。

（2）SB增强草鱼的肠道部分免疫功能：

（i）增加LZ和ACP活性，C3，C4和IgM含量以及上调的bdefensin-1（除DI），hepcidin，LEAP-2B（LEAP-2A除外）和粘蛋白-2 mRNA水平。

04 分析

04 Discussion

（ii）下调促炎细胞因子TNF-α，IFN-g2，IL-1b（除PI），IL-6，IL-8，IL-15（除PI），IL-17D（除PI），IL-12p35和IL-12，p40（除PI或MI）mRNA水平，并且上调了抗炎细胞因子IL-10，IL-11（除PI），TGF-β1（除PI），TGF-b2（除PI），IL-4 / 13A和IL-4 / 13B三个肠段中的mRNA水平。上述细胞因子可能参与NF-kB信号通路IKKβ（而不是PI）和IKKg / IkBα / NF-kB p65和c-Rel（除PI或MI）和p38MAPK信号通路（MAPKK6 / p38MAPK的）。

（3）对于幼龄草鱼的FE，MSB的功效比PSB高3.5倍。

（4）对于提升PWG，保护草鱼后肠肠道健康和LZ活性，最佳SB补充量为（MSB作为SB来源）160.8，339.9和316.2mg/kg。

THANK YOU

感谢聆听，批评指导