Animal-Derived Antimicrobial Peptides for Swine Production

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Zhejiang University, China

Sept. 26, 2012 Paris


Paris
Shanghai
China
Russia
Canada
United States of America
Brazil
Australia
Antarctica
Arctic Ocean
North Atlantic Ocean
North Pacific Ocean
South Pacific Ocean
South Atlantic Ocean
Indian Ocean


HEILONGJIANG
JILIN
XINJIANG
GANSU
QINGHAI
XIZANG
SICHUAN
HUBEI
ANHUI
SHANGHAI
ZHEJIANG
HUNAN
JIANGXI
FUJIAN
GUIZHOU
YUNNAN
GUANGXI
GUANGDONG
HONG KONG
TAIWAN
HAINAN
Shanghai
Hangzhou
Zhejiang University

Five campuses

Zijingang

Yuquan

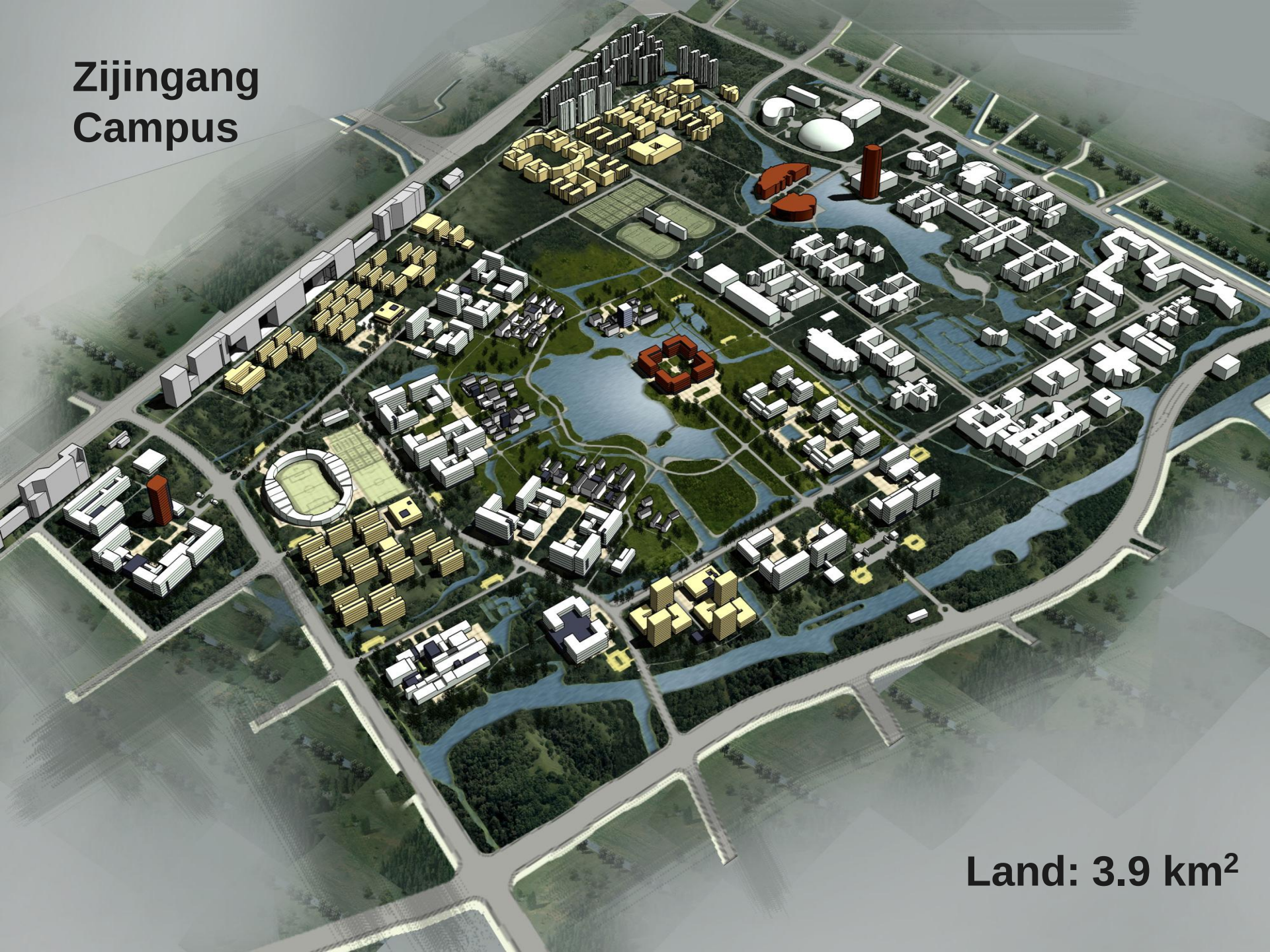
Xixi

Huajiachi

Zhijiang

Land: 6 km^2

Floor Space: 2M m^2


Zijingang
Campus
Land: 3.9 km²

A Comprehensive University

- **Academics (37 departments/colleges)**
  - **Agricultural, Life and Environment:**

    Life Science; Biosystem Engineering & Food Science; Environment & Resource; Agriculture and Biotechnology; **Animal Sciences**
  - **Engineering**
  - **Humanities**
  - **Information Technology**
  - **Medicine**
  - **Science**
  - **Social Science**
- **6 affiliated hospitals**

A Large University

Some figures in 2011:

- **8,222 Faculty and staff members**
  - **3,146 full-time faculty**
  - **1,282 full professors**
  - **1,352 associate**
- **89,269 Students**
  - **22,664 undergraduates (full-time)**
  - **26,605 graduate students (including 7,737 Ph.D. students)**
  - **40,000 course or adult and distance-education students**

A Top-ranking University in China

According to:

- **Chinese Universities' Ranking 2009**
- **Chinese Universities' Ranking 2010**
- **Chinese Universities' Ranking 2011**

(http://edu.sina.com.cn/focus/utop.html)

Zhejiang University ranks third nationally

My research group:

Research Area

Swine Nutrition

Research Content

- Swine Nutrition and Immunology
- Swine Nutrition and Meat quality


Jinhua


Tibet

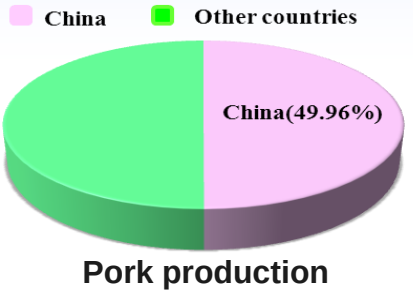

Laiwu


Rongchang


Landrace

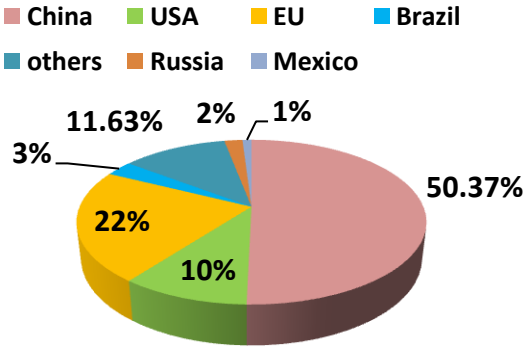
Swine industry is very important in China

- In 2011, global pork production: 101.13 million tons; pork production in China: 50.53 million tons (49.96% of the global).



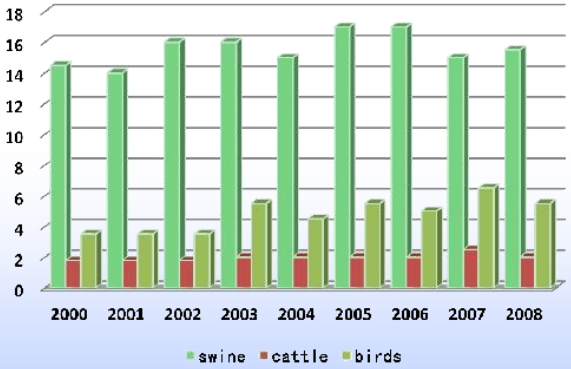
Pork production

- In 2011, The amounts of consumed pork in China :52.58 million tons (50.37% of the global).



The main pork consumer countries

- 2000-2008: The pork consumption *per capita* in China accounts for 75% of the total consumption of livestock products.



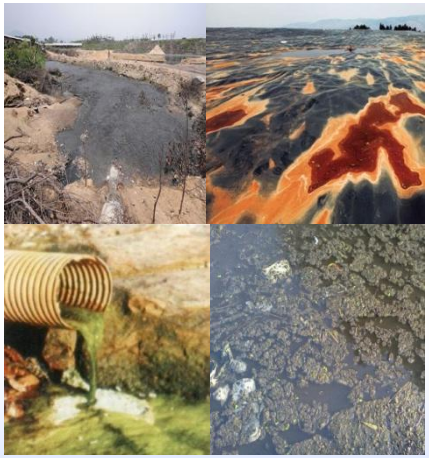
Consumption of livestock *per capita* in China

Challenges in swine production

1. Resource — Shortage of feed sources

2. Environment — Pollution of livestock manures

3. Health — Pork safety and meat quality



- **In recent years, only a few antibiotics, such as bambermycin, colistin sulfate, are permitted in feed in China.**
- **Thus, swine production is challenged by the risk of reduced growth performance, increased difficulty in disease control and increased health problems.**

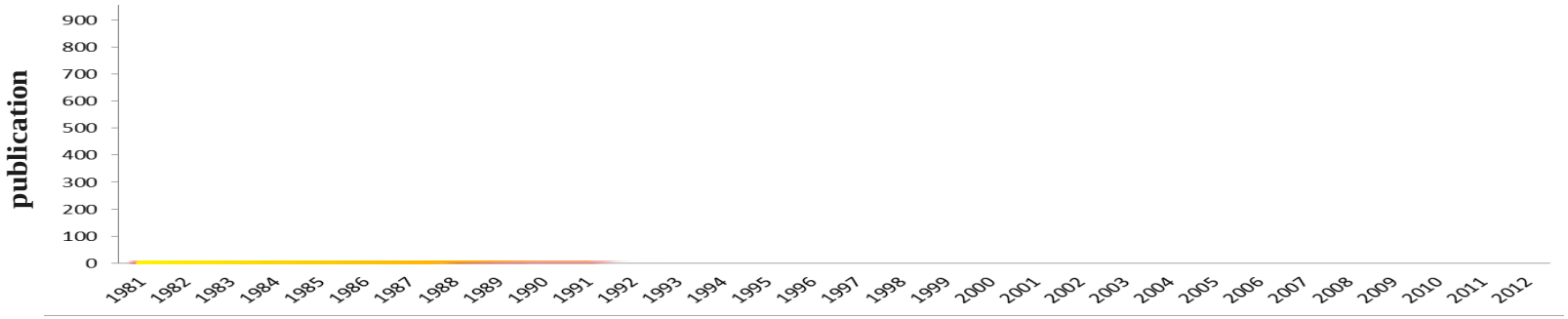
Development of alternatives to antibiotics to improve pig health and growth performance is urgent and promising!

Antimicrobial peptides（AMPs）

Since cecropin A and B were firstly purified from *Hyalophora cecropia* by Boman's group in 1980, AMPs have attracted widespread attention

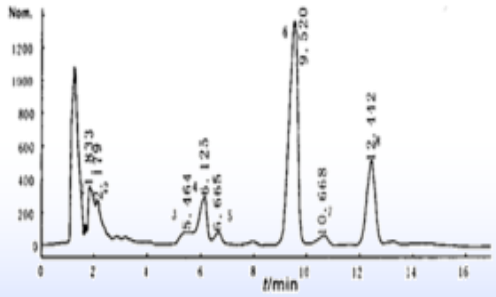
- **Distributed among multiple organisms**
- **Broad-spectrum antimicrobial activities**
- **Immunomodulatory activities**
- **Membrane disrupting mechanism, not inclined to develop drug resistance**

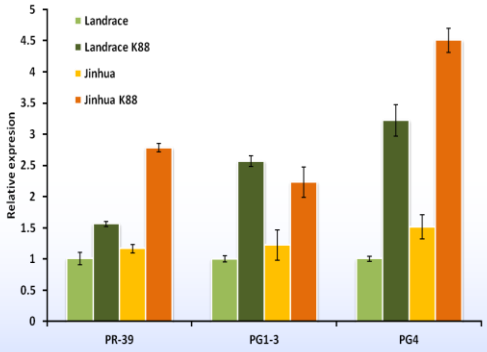
The papers focused on AMPs in recent years

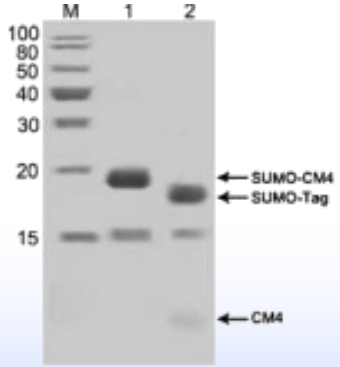


Scientific studies of AMPs in China

- **Purifying and screening of novel AMPs resources from Chinese species**
- **Developmental expression, breed differences of animal-derived AMPs and its nutritional regulation**
- **Molecular design and recombinant expression of AMPs**



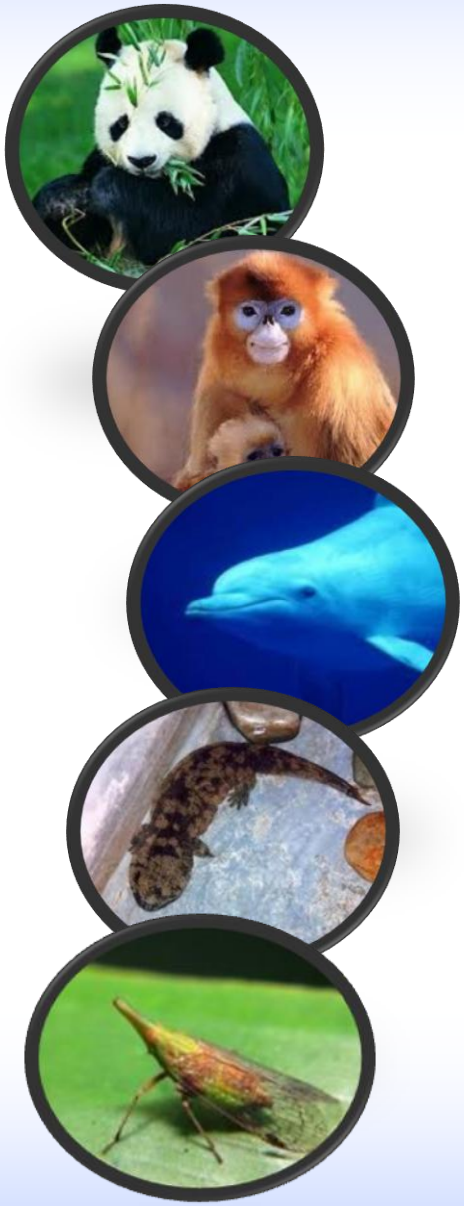




Purifying and screening of AMPs resources

China has a great diversity of plants and animals. There are 30,000 species of plants;17,000 species of invertebrates; 430 species of mammals…

Chinese researchers pay more attention to animal AMPs resources



Available online at www.sciencedirect.com

Developmental and Comparative Immunology (2008) 32, 1242–1247

ELSEVIER

Molecular

Available at www.sciencedirect.com

DCI

Developmental & Comparative Immunology

Available online 19 May 2012

DCI

Journal of proteome research

ARTICLE

pubs.acs.org/jpr

timicrobial

Extremely Abundant Antimicrobial Peptides Existed in the Skins of Nine Kinds of Chinese Odorous Frogs

Xinwang Yang,[†,‡] Wen-Hui Lee,[*,†] and Yun Zhang[*,†]

[†]Key Laboratory of Animal Models and Human Disease Mechanisms of Chinese Academy of Sciences & Yunnan Province, Kunming Institute of Zoology, Kunming, Yunnan 650223, China

[‡]Graduate School of the Chinese Academy of Sciences, Beijing 100049, China

nsects & Rodents,

t, Beijing 100101, PR

Purifying and screening of AMPs resources

- Lai *et al.* identified **107 novel AMPs** from skin of the frog *Odorrana grahami*.,and isolated AMPs with antioxidant properties from the skin secretions of a species of frog that lives in the subtropical plateau (altitude around 2300m). So far, **more than 500 AMPs** were identified by Lai's group, which accounts for **25%** of the total number of AMPs.*(Mol Cell Proteomics, 2007 & Mol Cell Proteomics, 2009)*

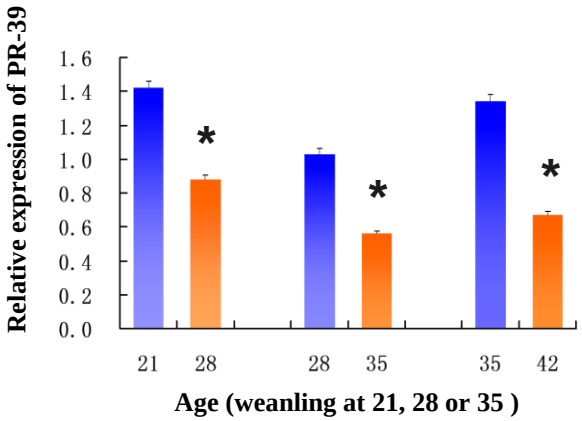
- Wang *et al.* identified one cathelicidin-like AMP named cathelicidin-BF from the snake venom of *Bungarus fasciatus*. It efficiently kills bacteria and fungal species with very low hemolytic and cytotoxic activities towards eukaryocyte. *(PLoS One, 2008)*

- Zhang *et al.* identified 69 AMP-like genes from seven ant genomes *(Dev Comp Immunol, 2012)*

- ……

Developmental expression, breed differences, nutritional regulation of AMPs in pigs

- Wang *et al.* reported lower expression level of AMPs in piglets and weaning significantly decreased PG-1 and PR-39 mRNA expression of piglets.*(Journal of Dairy Science 2005)*



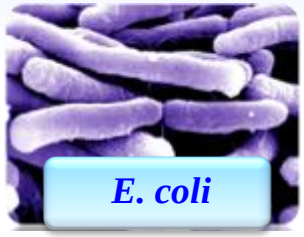
- Chen *et al.* reported the higher expression of pBDs might be the reason that Meishan and Tibetan pigs have higher immunity and disease resistance than crossbred pigs.*(Livestock science 2009, Molecular Biology Reports 2010)*

- Wang *et al.* studied effect of zinc, lactoferrin, polysaccharide on AMPs gene expression in piglets. *(Journal of Animal and Feed Sciences.2006; Journal of Animal Science.2007)*

- ……

Recombinant expression studies of AMPs

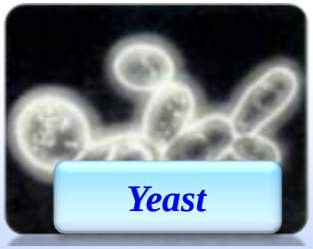
- Xie *et al.* has recombinantly expressed frog antibacterial peptide OG using different molecular partner in *E. coli.*(*Protein and peptide letters 2012*)



- Chen *et al.* has recombinantly expressed active cecropin AD in *B. Subtillis* and the expression level was 30.6mg/L.(*Antimicrobial agents and chemtherapy 2009*)

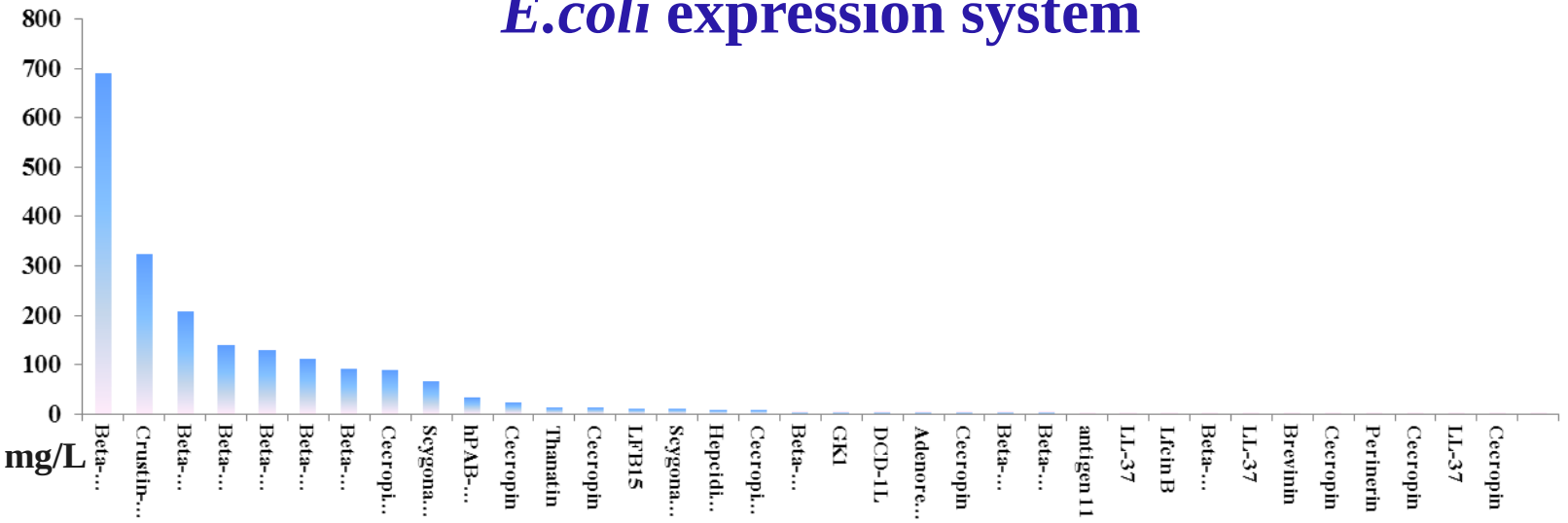
- Zhou *et al.* utilized *Lactobacillus* to express apidaecin directly and the expression level was 10mg/L.(*Appl Microbiol Biotechnol 2008*)

- Wang *et al.* utilized *P.pastoris* SMD1168 strain to recombinantly express hybrid peptide cecropinA-maganin.(*Experimental Biology and Medicine 2012*)

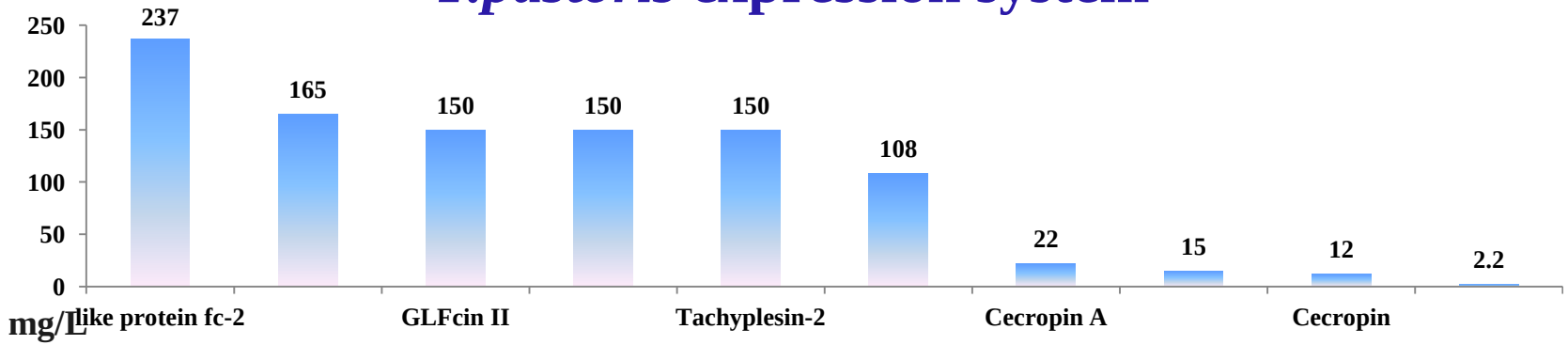


Recombinant expression studies of AMPs

E.coli expression system

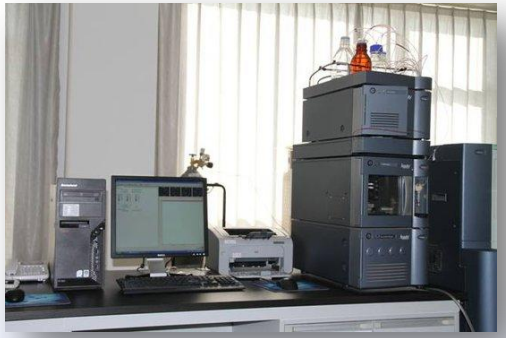


P.pastoris expression system



Problems of AMPs research in China

- Difficulty in purifying and screening
- Low expression and high cost
- Far from application in animal production



My research group focuses on:

1. **Comparative study of antibacterial activity, cytotoxicity, mechanisms of animal-derived AMPs and molecular design**

2. **Effect of animal-derived AMPs on the barrier function of pig intestinal epithelial cells(IPEC-J2)**

3. **Developmental expression, breed differences of swine AMPs and nutritional regulation**

1.1 Antimicrobial activity of animal derived AMPs

Antimicrobial activity of animal-derived AMPs *in vitro*

- ✓ **Human : LL-37**
- ✓ **Pig : protegrin-1(PG-1), PMAP-23, porcine lactoferricin (LFP-20)**
- ✓ **Cattle : bovine lactoferricin (Lfcin B), indolicidin (IN)**
- ✓ **Snake : cathelicidin-BF (C-BF)**
- ✓ **Frog : plastrin-OG1 (OG1)**
- ✓ **Insect : cecropin A (CA), cecropin P1 (CP1)**

Table 1 MICs of animal-derived AMPs against pathogenic bacteria

	MICs (μg/mL)											
Gram-negative	**LL-37**	**PG-1**	**PMAP-23**	**LFP-20**	**IN**	**LfcinB**	**C-BF**	**OG1**	**CA**	**CP1**	**Aureo-mycin**	**Neom-ycin**
E. coli ATCC25922	16	8	128	64	16	16	1	16	16	4	4	2
E. coli K88	32	8	256	32	16	64	4	32	16	4	4	1
E. coli K12	256	8	256	128	16	128	1	32	32	8	2	2
E. coli EPEC O78:K80	-	32	-	256	16	256	16	128	64	32	64	1
E. coli EPEC O144:K74	-								128	128	4	1
S. choleraesuis CMCC50020	128	4	-	128	32	32	2	128	32	8	4	2
S.typhimurium CMCC50013	128	4	-	64	16	32	4	128	16	8	4	2
S. enteritidis CMCC50041	-	16	-	256	16	256	4	128	-	16	16	8
P. aeruginosa CMCC27853	128	8	-	256	128	128	4	-	32	16	2	4
Gram-positive												
S. aureus ATCC25923	16	2	64	64	4	16	4	16	-	256	0.06	0.13
S. epidermidis ATCC12228	256	4	256	128	8	32	8	32	-	256	0.13	0.5

Antimicrobial activity of PG-1 and C-BF are higher.

F.F. Han, Y.Z. Wang et al .World J. Microbiol.Biotechnol, 2011

Y.F. Liu, Y.Z. Wang et al . INT J PEPT RES THER , 2011

Table 1 MICs of animal-derived AMPs against pathogenic bacteria

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E. coli EPEC O78:K80	-	32	-	256	16	256	16	128	64	32	64	1
E. coli EPEC O144:K74	-								128	128	4	1
S. choleraesuis CMCC50020	128	4	-	128	32	32	2	128	32	8	4	2
S.typhimurium CMCC50013	128	4	-	64	16	32	4	128	16	8	4	2
S. enteritidis CMCC50041	-	16	-	256	16	256	4	128	-	16	16	8
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Gram-positive												
S. aureus ATCC25923	16	2	64	64	4	16	4	16	-	256	0.06	0.13
S. epidermidis ATCC12228	256	4	256	128	8	32	8	32	-	256	0.13	0.5

Antimicrobial activity of LFP-20 and Lfcin B are lower.

F.F. Han, Y.Z. Wang et al .World J. Microbiol.Biotechnol, 2011

Y.F. Liu, Y.Z. Wang et al . INT J PEPT RES THER , 2011

Table 2. MICs of animal-derived AMPs against beneficial bacteria

	MICs (μg/mL)	
	L. acidophilus ATCC4356	*S. bifidobacterium* ATCC27533
LL-37	-	-
PG-1	128	-
PMAP-23	-	-
LFP-20	-	-
IN	-	32
LfcinB	-	-
C-BF	-	-
OG1	128	32
CA	-	-
CP1	-	-
aureomycin	32	8
neomycin	4	256
oxytetracycline	256	32
zinc bacitracin	64	1
colistin sulfate	256	64

AMPs had less inhibitory effect on beneficial bacteria, while antibiotics showed high bacteriocidal activity against beneficial bacteria.

1.2 Cytotoxicity of animal-derived AMPs

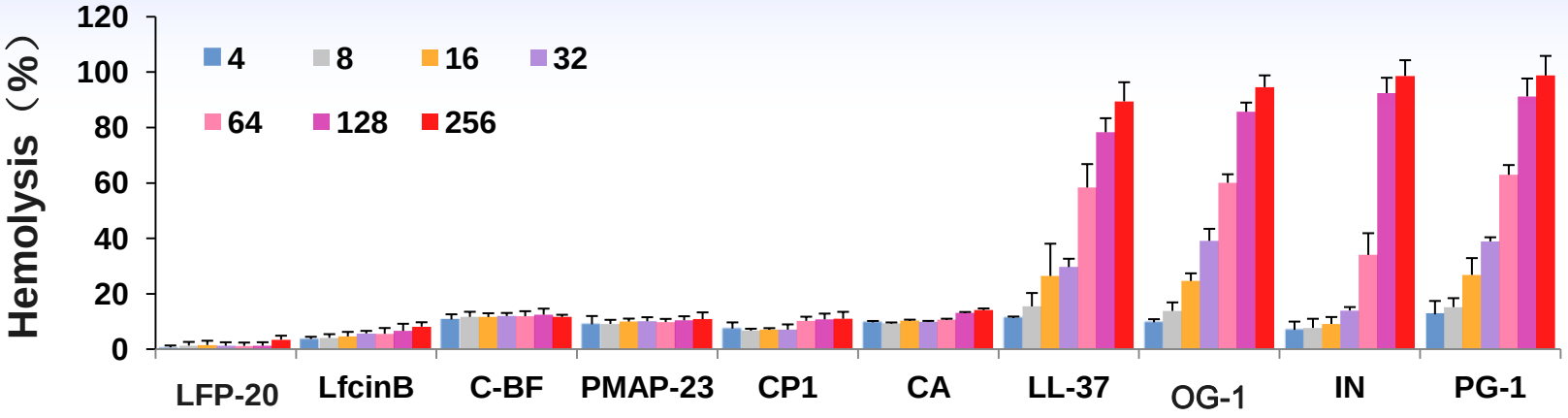


Fig. 1 Hemolysis of animal-derived AMPs

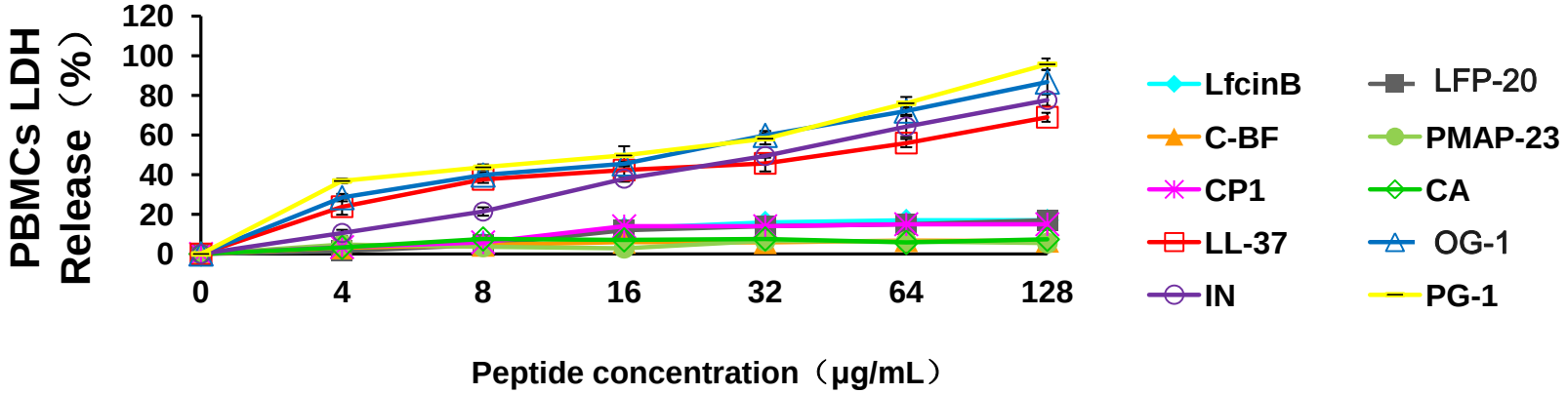


Fig. 2 LDH release of PBMCs induced by animal-derived AMPs

LFP-20 and Lfcin B caused minimal erythrocyte lysis and did not exhibit cytotoxicities to PBMCs at all concentrations tested. In contrast, PG-1, OG1, LL-37 and indolicidin caused significant cytotoxicity against PBMCs and hemolytic activities, which were stronger than other peptides in a dose-dependent manner.

1.3 Mechanism of action

Membrane mechanism

- Morphological changes of *E.coli* ATCC 25922 and *S. aureus* ATCC25923
- Morphological changes of beneficial bacteria

SEM

Intracellular mechanism

- DNA binding activity of PG-1 and C-BF
- Effect of PG-1 and C-BF on the bacterial protein synthesis

TEM

Morphological changes by SEM (Pathogenic bacteria)

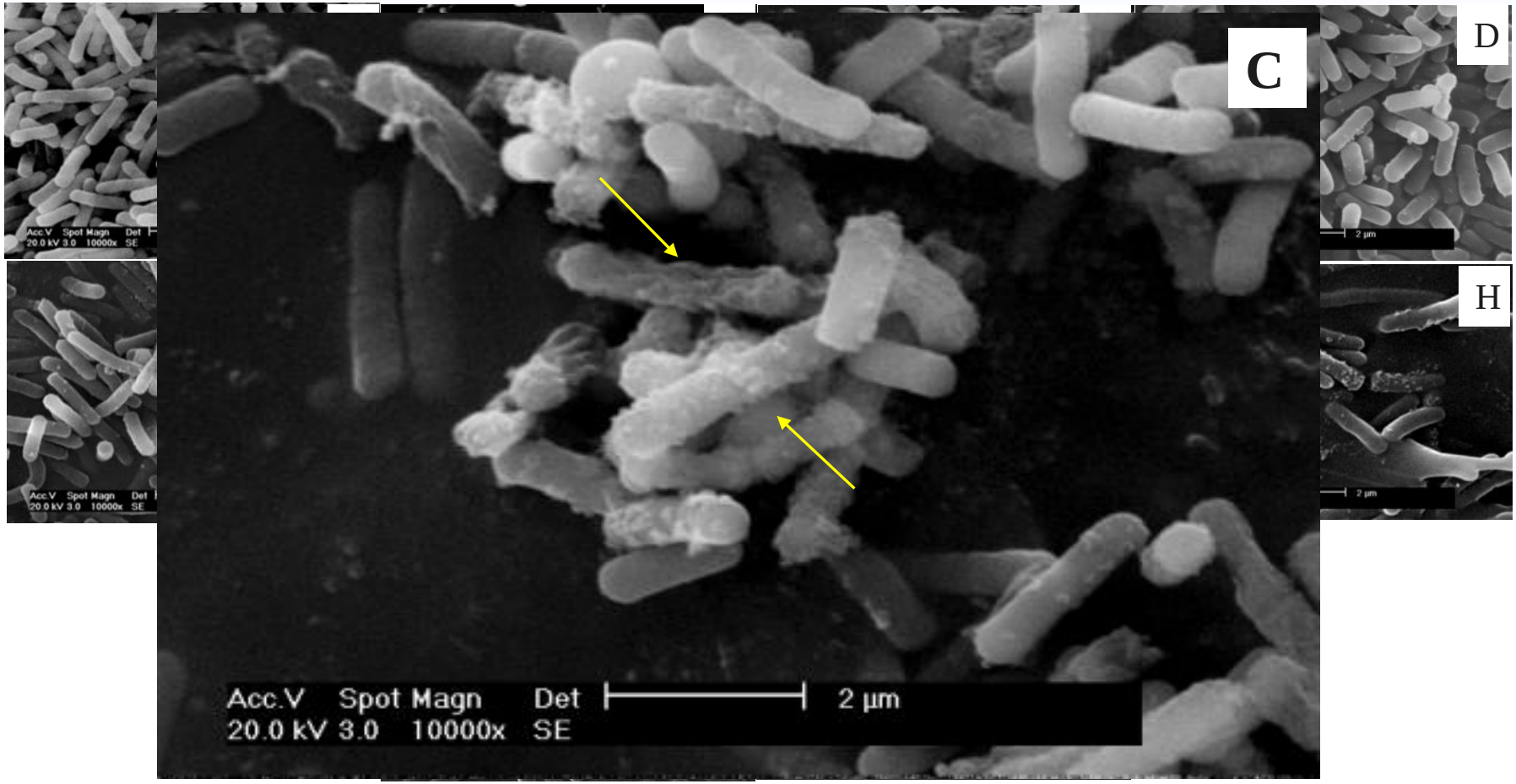


Fig. 3 Membrane-disrupting effect of animal-derived AMPs on *E.coli* ATCC 25922

A .Control ; B. LL-37; C. PG-1; D. PMAP-23; E. LFP-20; F. C-BF; G. CA; H. CP1; I. IN; J. LfcinB

Morphological changes by TEM (Pathogenic bacteria)

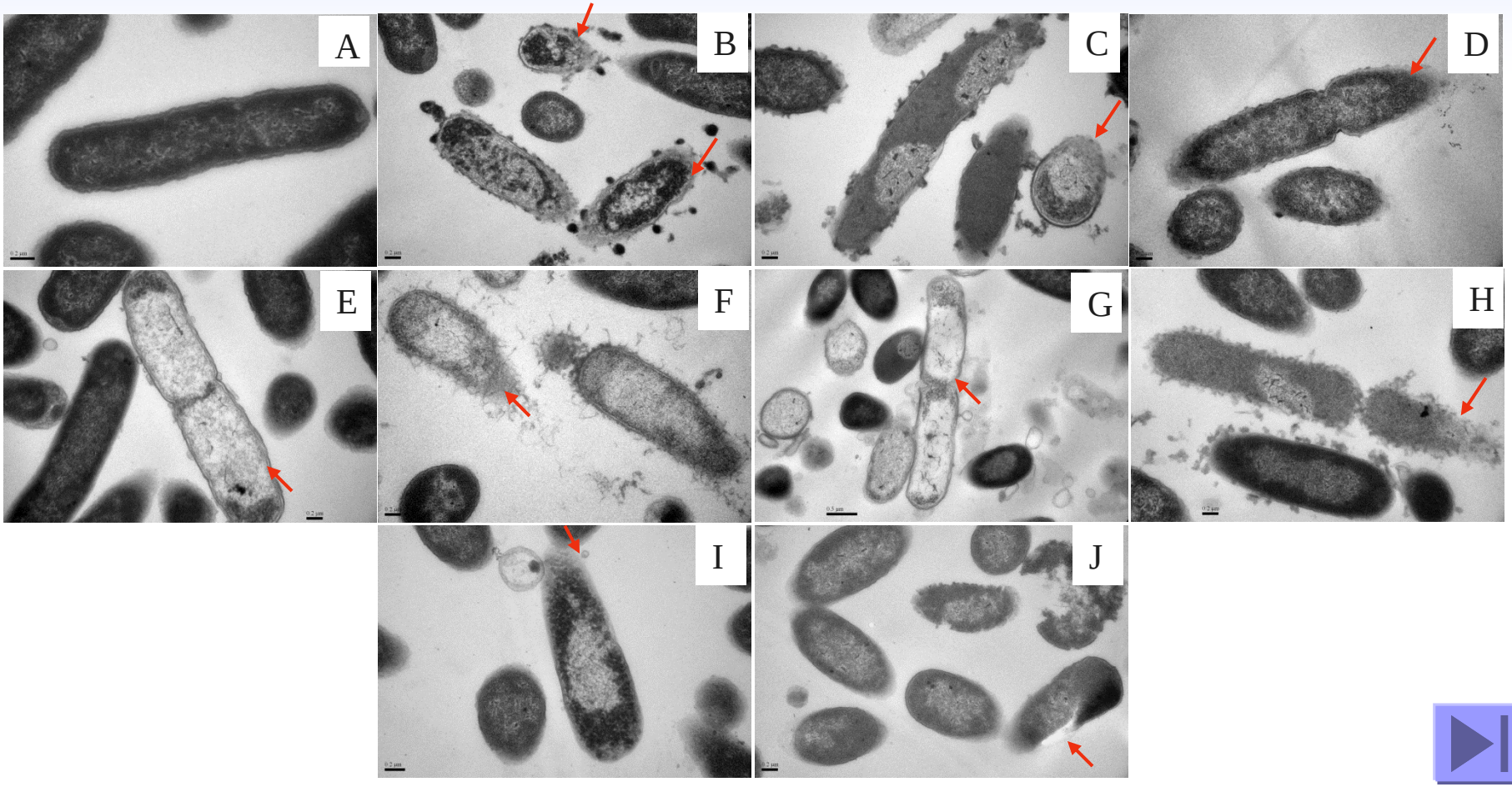


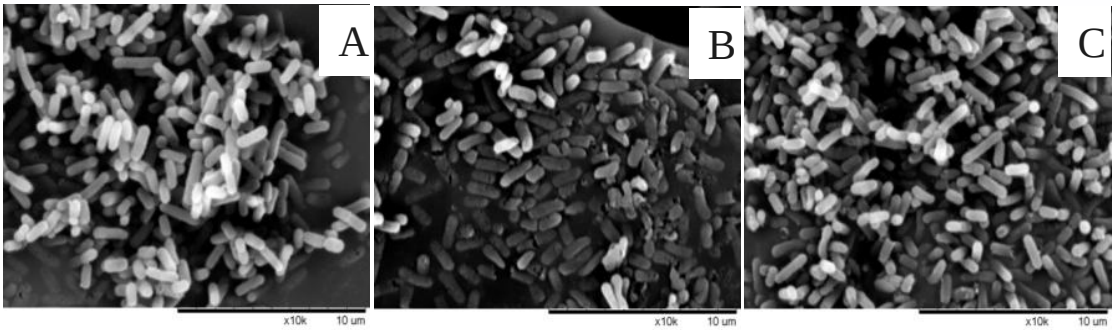
Fig. 4 Membrane-disrupting effect of animal-derived AMPs on *E.coli* ATCC 25922

A . Control; B. LL-37; C. PG-1; D. PMAP-23; E. LFP-20; F. C-BF; G. CA; H. CP1; I. IN; J. LfcinB

Mechanism of AMPs against *S. aureus* ATCC25923 is similar to *E.coli* ATCC 25922

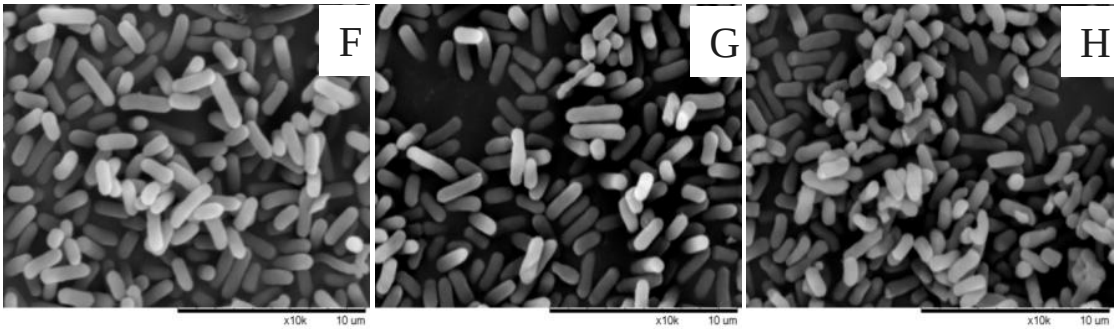
Morphological changes by SEM (Beneficial bacteria)

L. acidophilus ATCC4356



control IN OG1 aureomycin neomycin

S.Bifidobacterium ATCC27533

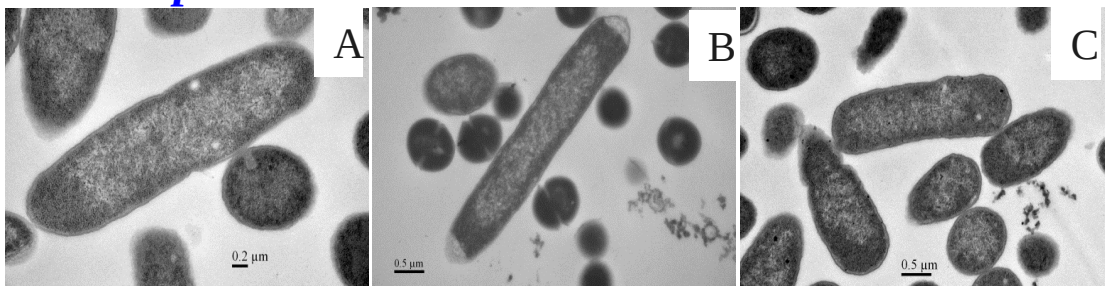


control IN OG1 aureomycin neomycin

Fig. 5 Membrane-disrupting effect of animal-derived AMPs on *L. acidophilus* ATCC4356 and *S.Bifidobacterium* ATCC27533

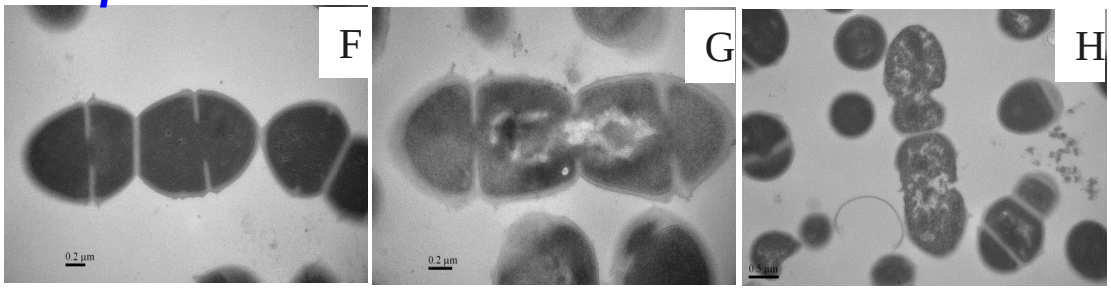
Morphological changes by TEM (Beneficial bacteria)

L. acidophilus ATCC4356



control IN OG1 aureomycin neomycin

S.Bifidobacterium ATCC27533



control IN OG1 aureomycin neomycin

Fig. 6 Membrane-disrupting effect of animal-derived AMPs on *L. acidophilus* ATCC4356 and *S.Bifidobacterium* ATCC27533

Intracellular mechanism

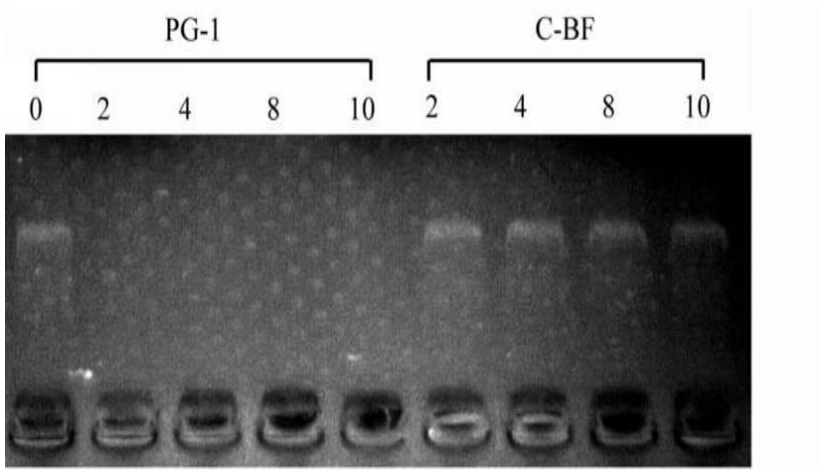


Fig. 7 DNA binding activity of PG-1 and C-BF

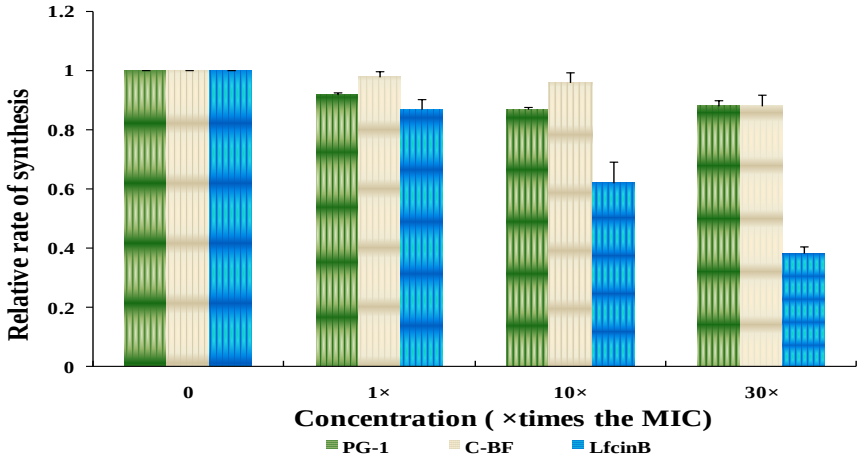


Fig.8 Effect of PG-1 and C-BF on the bacterial protein synthesis

Binding was assayed by the inhibitory effect of peptides on the migration of DNA. The weight ratio (peptide:DNA) is indicated above each lane

Effect of PG-1 and C-BF on the bacterial protein synthesisin a cell-free assay at 1×, 10×and 30×MIC, respectively.

1.4 Molecular design of animal derived AMPs

AMPs	Advantages	Disadvantages
LFP-20, Lfcin B	Low cytotoxicity	Low antimicrobial activity
PG-1	High antimicrobial activity	High cytotoxicity
C-BF	High antimicrobial activity & low cytotoxicity	Few reports

- **Molecular design of LFP-20**

Remove disulfide bond

Change molecular hydrophobic

Increase the proportion of aromatic amino acids

→ **LF-2, LF-4, LF-6**

- **Molecular design of PG-1**

Hybridization with Lfcin B

→ **LB-PG**

Molecular design of LFP-20

Table 3 MICs of LFP-20 and analogs

	MICs （μg/mL）			
	LFP-20	LF-2	LF-4	LF-6
Gram negative bacteria				
E.coli ATCC 25922	64	4	8	8
E.coli K88	32	4	16	4
E.coli K12	128	8	16	4
E.coli C339	128	8	8	8
E.coli C343	256	8	8	4
E.coli UB1005	64	8	8	4
P. aeruginosa CMCC10104	256	8	8	16
S. choleraesuis CMCC 50020	128	16	16	4
S. typhimurium CMCC 50013	64	32	32	32
Gram positive bacteria				
S.aureus ATCC 25923	64	8	64	16
S.epidermidis C621	128	16	32	16

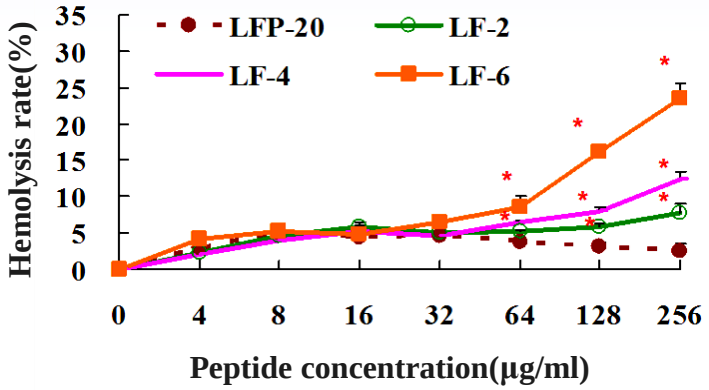


Fig. 9 Hemolysis rate of LFP-20 and analogs to porcine erythrocyte

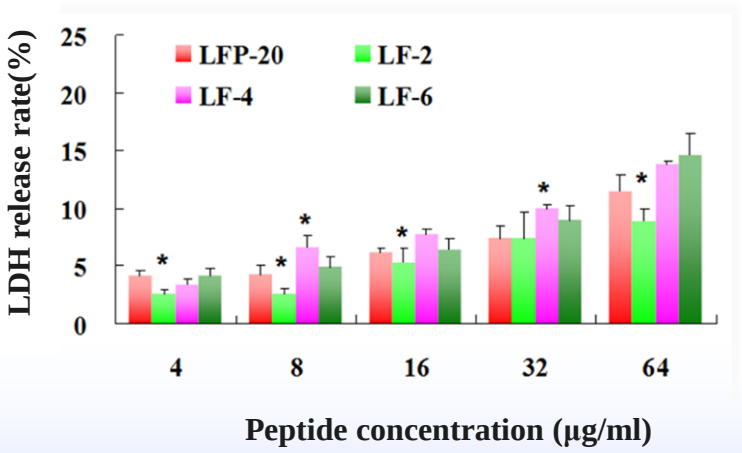


Fig. 10 Influence of LFP-20 and analogs on LDH release of porcine PBMCs

Molecular design of PG-1

Table 4 MICs of PG-1 and analogs

	MICs (μg/mL)		
	PG-1	LfcinB	LB-PG
Gram negative bacteria			
E. coli ATCC25922	8	32	8
E. coli K88	8	64	8
E. coli K12	8	32	8
E. coli EPEC O78:K80	32	128	16
S. choleraesuis CMCC50020	4	64	8
S. typhimurium CMCC50013	4	32	8
P. aeruginosa CMCC27853	8	128	16
Gram positive bacteria			
S. aureus ATCC25923	2	16	8
S. epidermidis ATCC12228	4	16	8
Benificial bacteria			
S. Bifidobacterium ATCC27533	128	-	-
L. Acidophilus ATCC4356	-	-	-

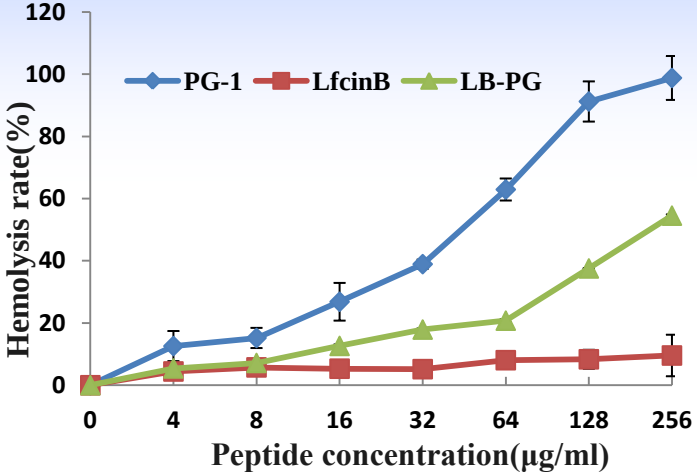


Fig. 11 Hemolysis rate of PG-1 and analogs to porcine erythrocyte

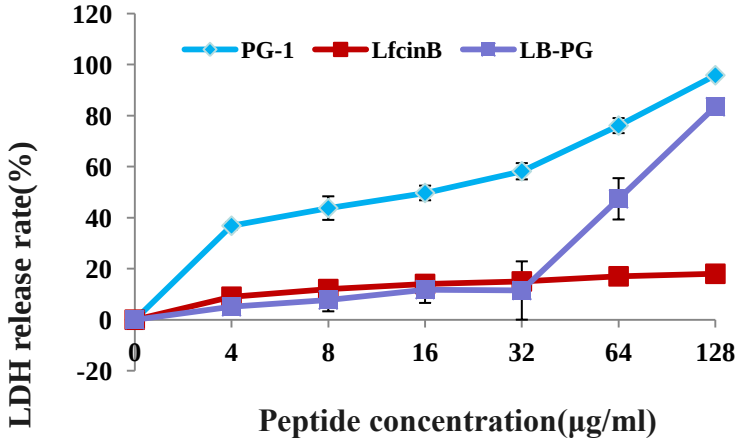


Fig. 12 Influence of PG-1 and analogs on LDH release of porcine PBMCs

Y.F. Liu, Y.Z. Wang et al .Biomaterials, 2012, accepted)

Summary (1)

- **The activity of different animal-derived AMPs is variable. Some AMPs showed strong activity with high cytotoxicity, while some AMPs showed low cytotoxicity with weak activity.**
- **Most tested AMPs killed bacteria by membrane disruption. Some AMPs may have intracellular targets.**
- **By the strategy of deleting the intramolecular disulfide bond, changing the proportion of hydrophobic amino acids, molecular hybridization, AMPs with more potent activity and lower cytotoxicity have been designed.**

My research group focuses on:

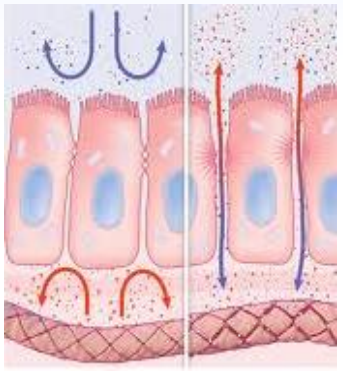
1. Comparative study of antibacterial activity, cytotoxicity, mechanisms of animal-derived AMPs and molecular design

2. **Effect of animal-derived AMPs on the barrier function of pig intestinal epithelial cells (IPEC-J2)**

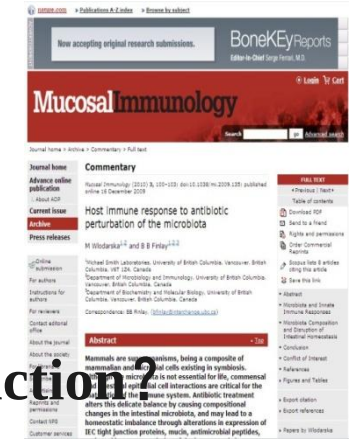
3. **Developmental expression, breed differences of swine AMPs and nutritional regulation**

Background

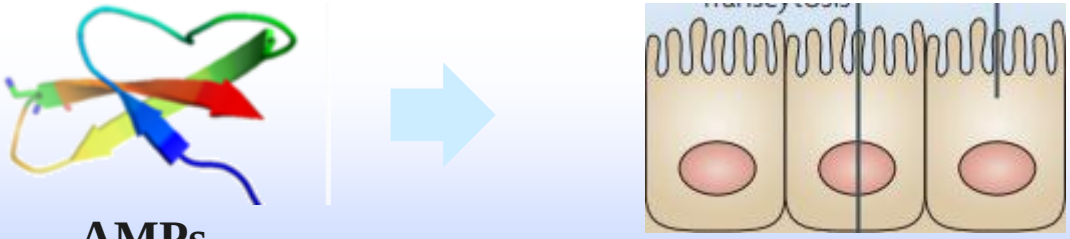
- Pig intestinal epithelium plays very important role in nutrient absorption, barrier function and immunity.



- In 2010, Wlodarska *et al* reported antibiotic treatment may lead to a homeostatic imbalance through alterations in expression of IEC tight junction proteins, mucin, antimicrobial peptides and cytokines. *(Nature Mucosal Immunology)*



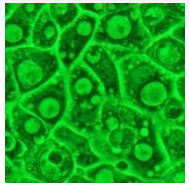
- Effects of AMP on pig intestinal epithelium barrier function?



AMPs

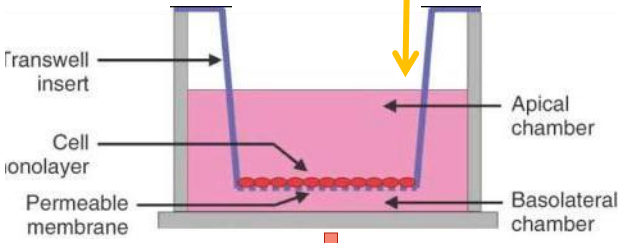
Methods

porcine intestinal epithelial cells (IPEC-J2)



+ AMPs (co-culture)

— LPS

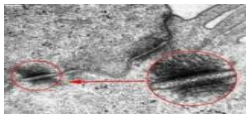


TEM

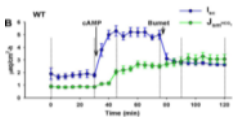
Ussing Chamber

qRT-PCR+Western

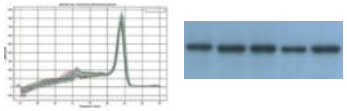
Confocal



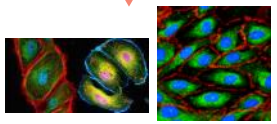
tight junction (TJ) structure



nutrient absorption and barrier integrity



expression level of TJ proteins

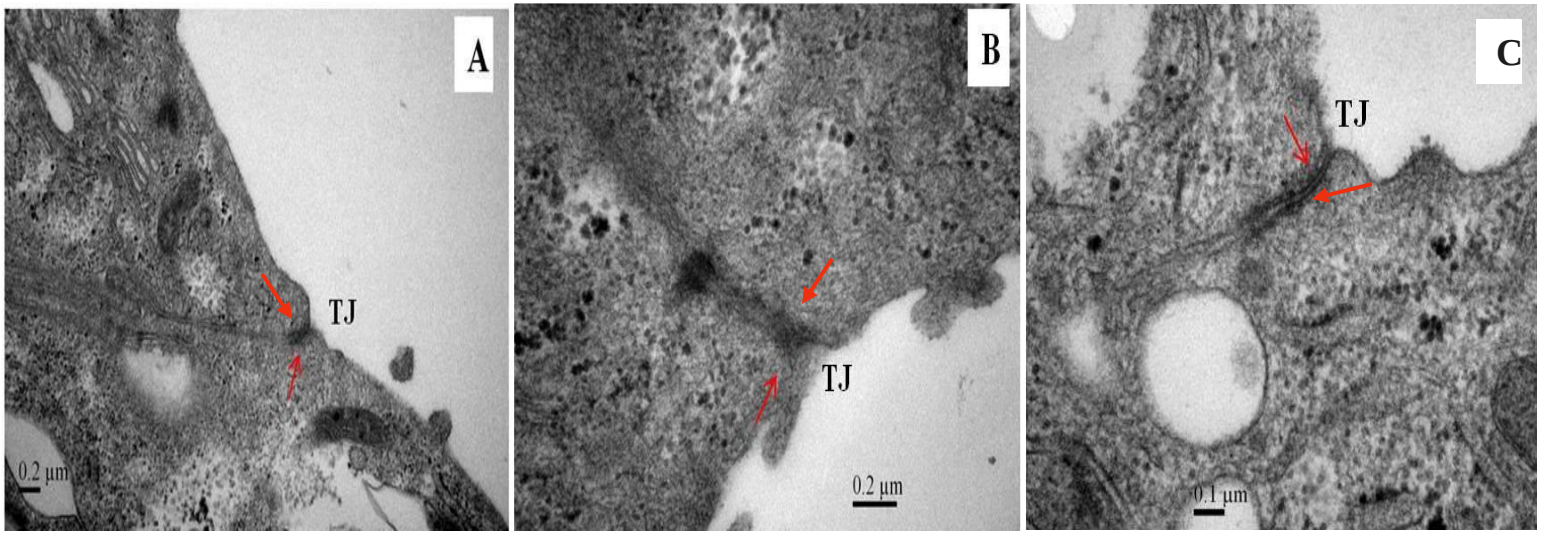


distribution of TJ proteins

Effect of AMPs on intestinal epithelial barrier function of pig

Results

2.1 Effect of AMP on structure of intestinal epithelial tight junction (TJ) of pig



Control **LPS** **C-BF + LPS**

Fig. 13 Effect of C-BF on TJ structure under LPS stimulation

Exposure to LPS markedly opened the TJ structure of IPEC-J2. C-BF treatment significantly attenuated the TJ structural abnormalities induced by LPS.

2.2 Effect of AMP on absorption function and barrier integrity of IPEC-J2 (by Ussing Chamber)

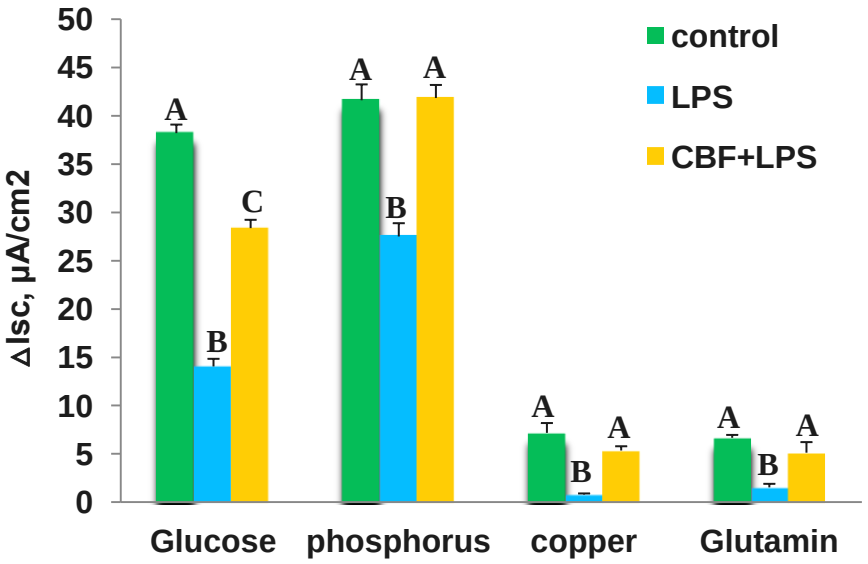


Fig. 14 Effect of C-BF on absorption function of IPEC-J2

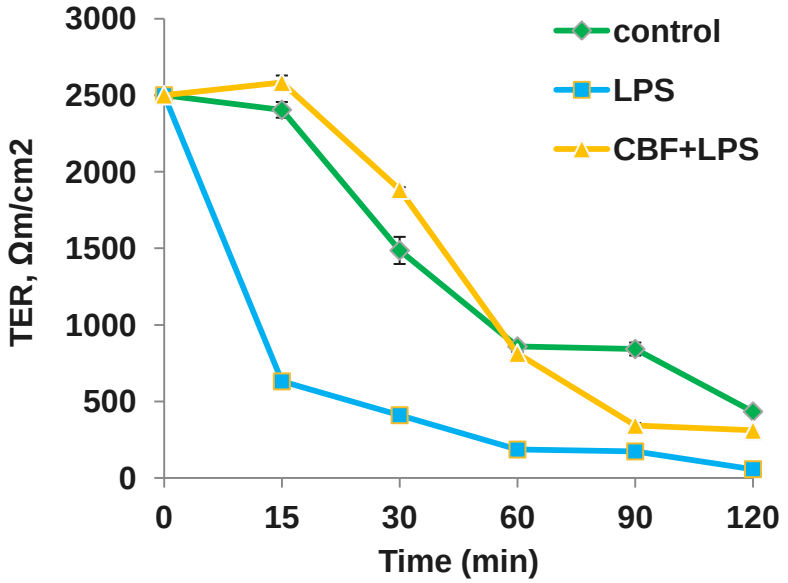


Fig. 15 Effect of C-BF on transepithelial electoral resistant (TER) of IPEC-J2

Exposure to LPS markedly reduced the nutrient absorption of IPEC-J2, and decreased TER in a short time (15 min), while C-BF treatment significantly relieved the decrease of absorption and TER in IPEC-J2. Similar results were observed in hybrid peptide LB-PG treatment.

2.3 Effect of AMP on the expression of TJ protein occludin and ZO-1 in IPEC-J2

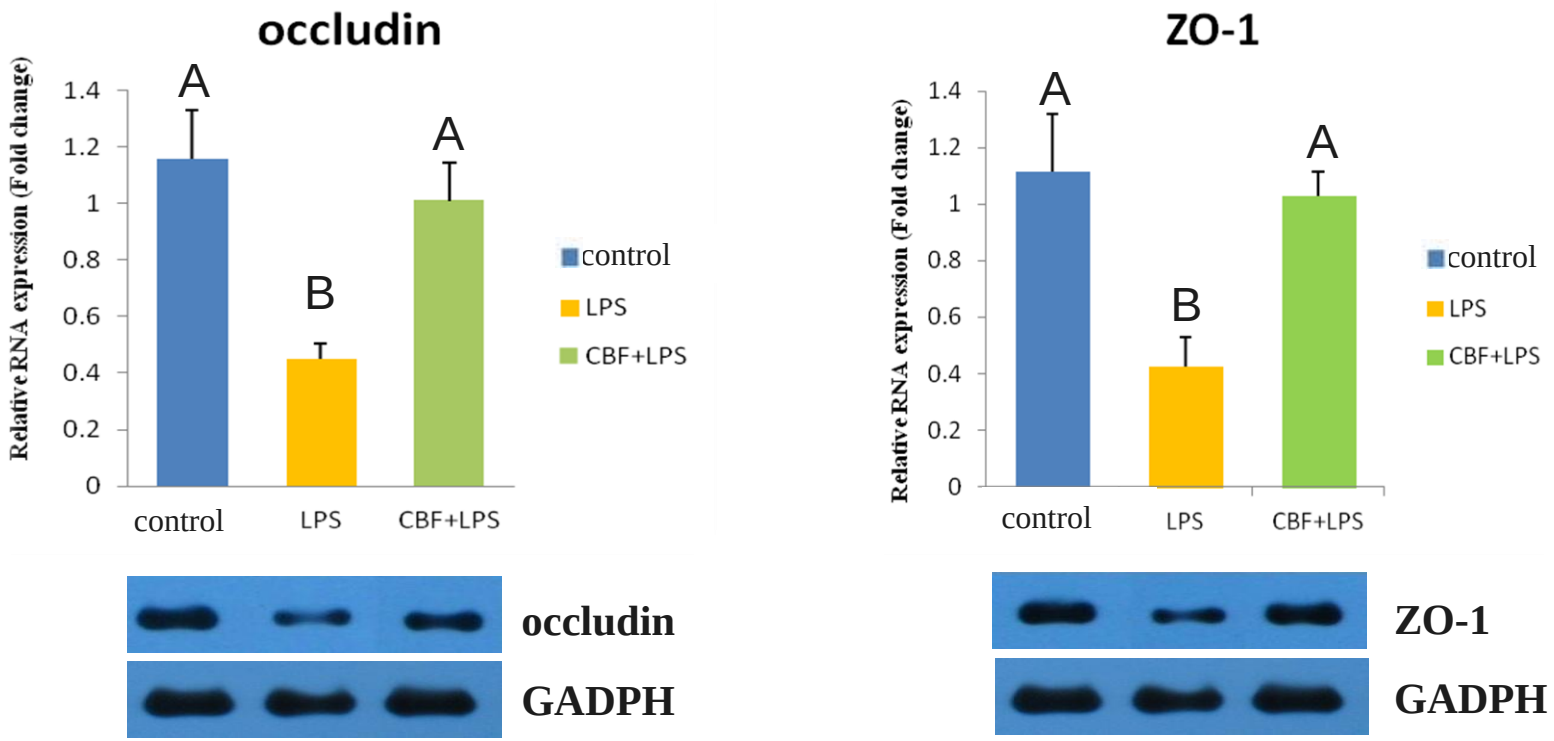


Fig. 16 Effect of C-BF on the expression of TJ proteins in IPEC-J2

LPS stimulation markedly inhibited the expression of TJ proteins, while co-culture with C-BF significantly restored the expression of occludin and ZO-1 at mRNA and protein levels.

2.4 Effect of AMP on the distribution of TJ protein occludin and ZO-1 (by Laser Confocal Microscopy)

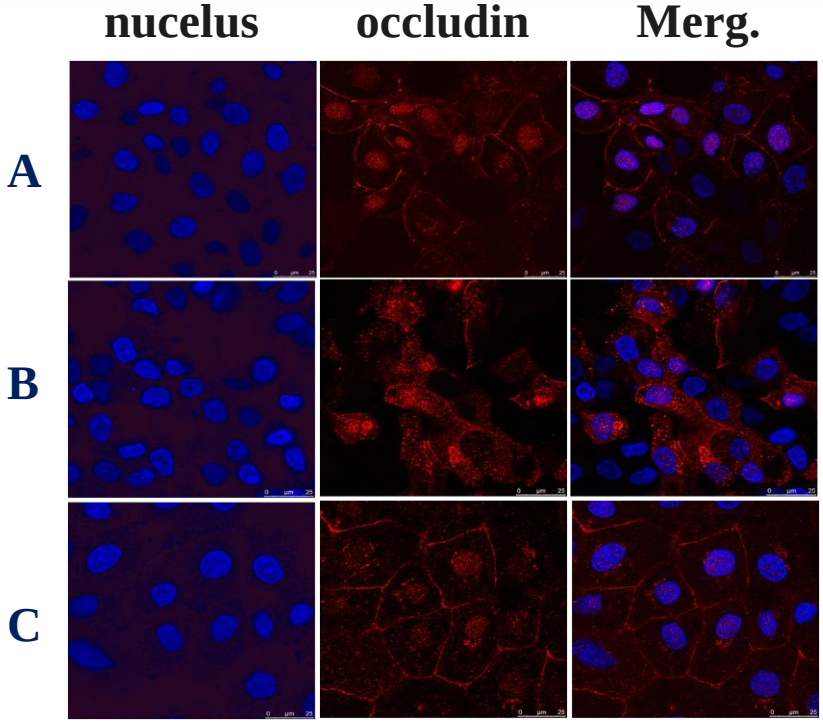


Fig. 17 Effect of C-BF on distribution of occludin in IPEC-J2

A. IPEC-J2; B. IPEC-J2 + LPS; C. IPEC-J2 + C-BF + LPS

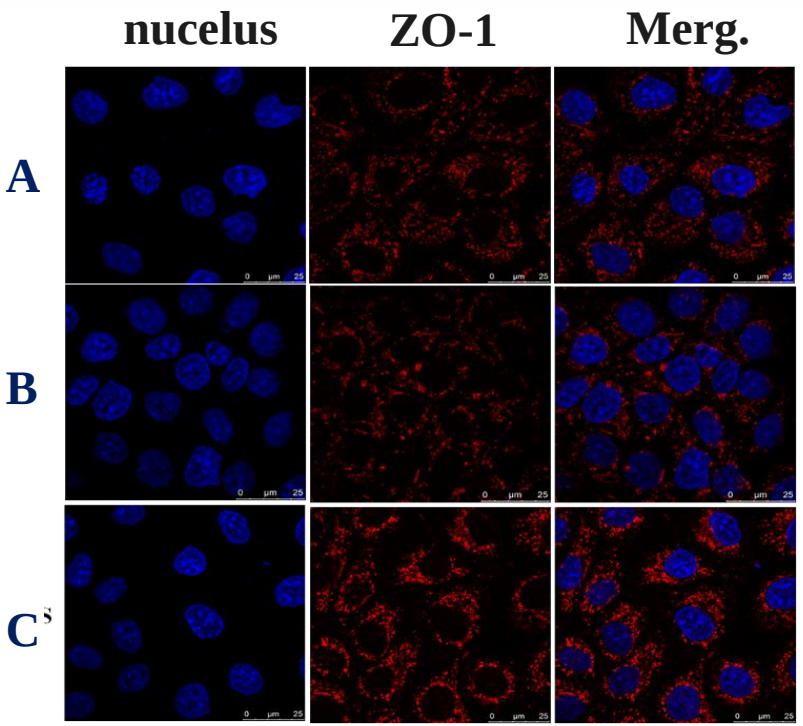


Fig. 18 Effect of C-BF on distribution of ZO-1 in IPEC-J2

A. IPEC-J2; B. IPEC-J2 + LPS; C. IPEC-J2 + C-BF + LPS

LPS markedly disrupted the normal distribution of occludin and ZO-1 in IPEC-J2. C-BF treatment significantly increased the expression of occludin and ZO-1 and attenuated the abnormal distribution induced by LPS.

Summary (2)

- AMP C-BF treatment markedly attenuated TJ structural abnormalities, reduced decrease of nutrient absorption and TER;
- AMP C-BF restored the expression of TJ protein occludin and ZO-1 at mRNA and protein levels, and attenuated the abnormal TJ distribution induced by LPS in IPEC-J2;
- Results above indicated that AMPs could protect the intestinal epithelial barrier function.

My research group focuses on:

1. Comparative study of antibacterial activity, cytotoxicity, mechanisms of animal-derived AMPs and molecular design

2. Effect of animal-derived AMPs on the barrier function of pig intestinal epithelial cells(IPEC-J2)

3. **Developmental expression, breed differences of swine AMPs and nutritional regulation**

3.1 Developmental expression of AMPs in pigs

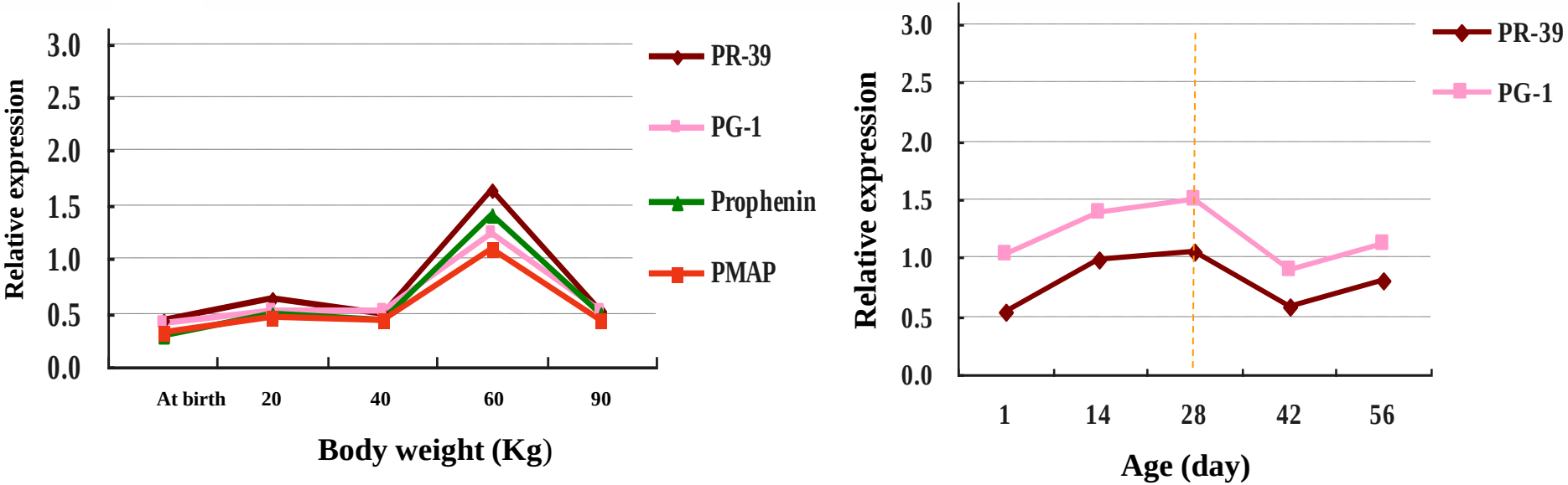
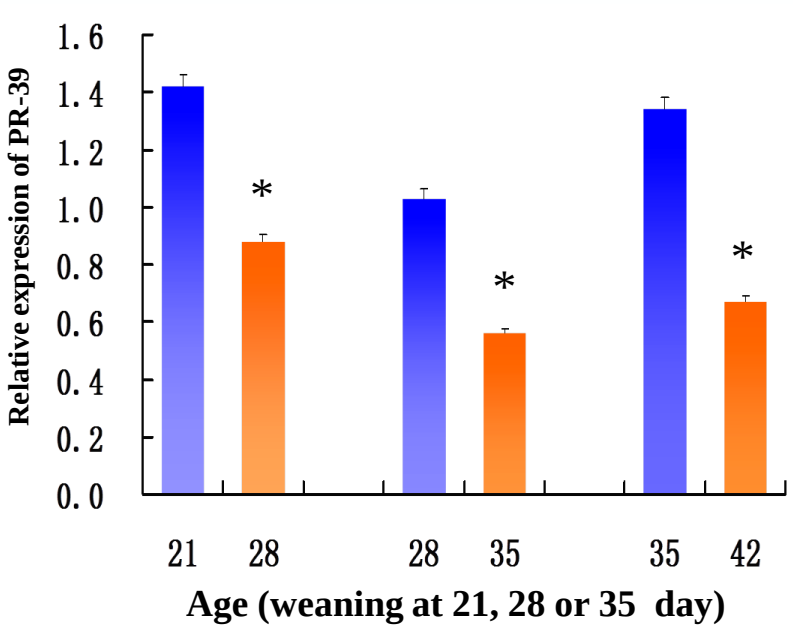


Fig. 19 Developmental expression of cathelicidins in pigs with different body weight

Gene expressions of porcine AMPs steadily increased from neonatal to 60 kg, but decreased significantly after 60 kg body weight .

3.2 Weaning dramatically reduced cathelicidin expression at different weaning age (21, 28, 35 day)



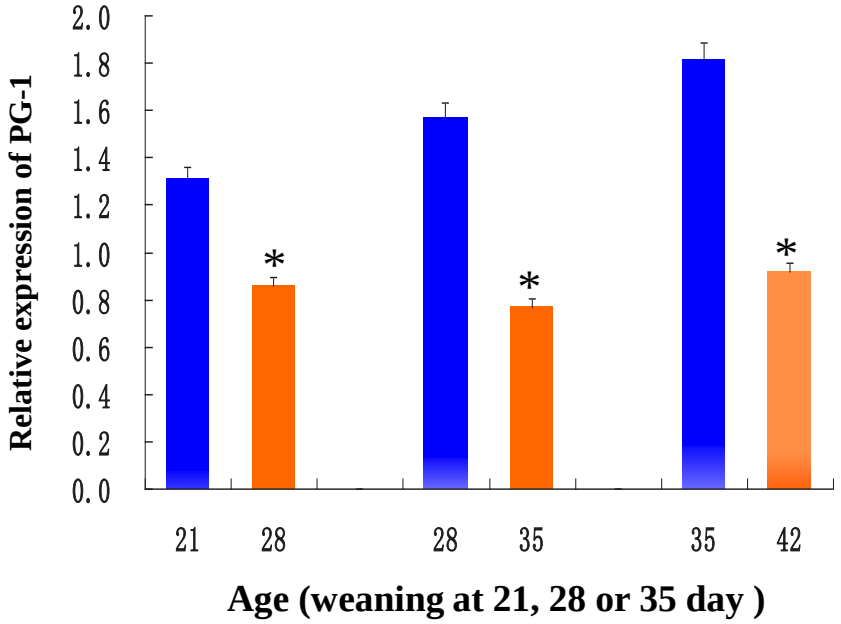


Fig. 20 Effect of weaning age on cathelicidin expression

3.3 Comparison of porcine cathelicidin expression between Chinese local pig breeds and Landrace

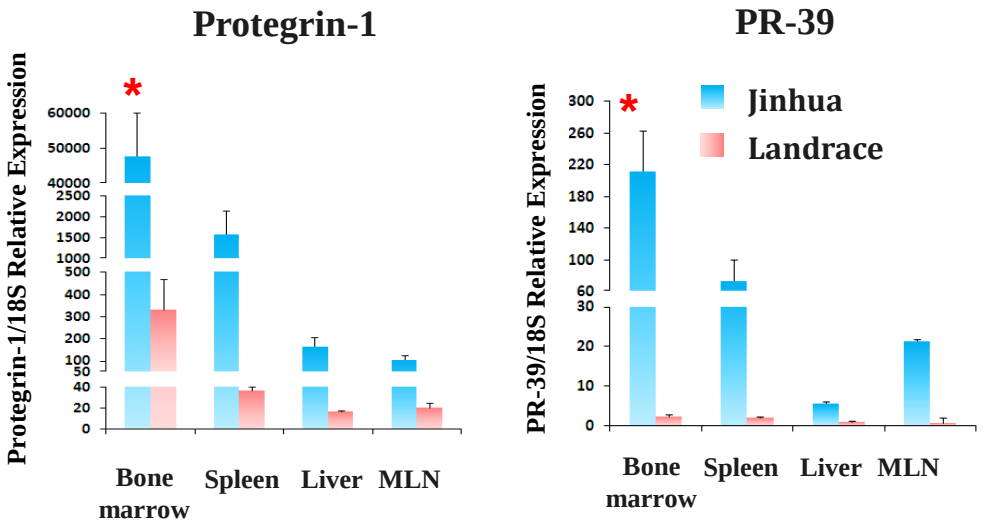


Fig. 21 Cathelicidin expression between Jinhua and Landrace

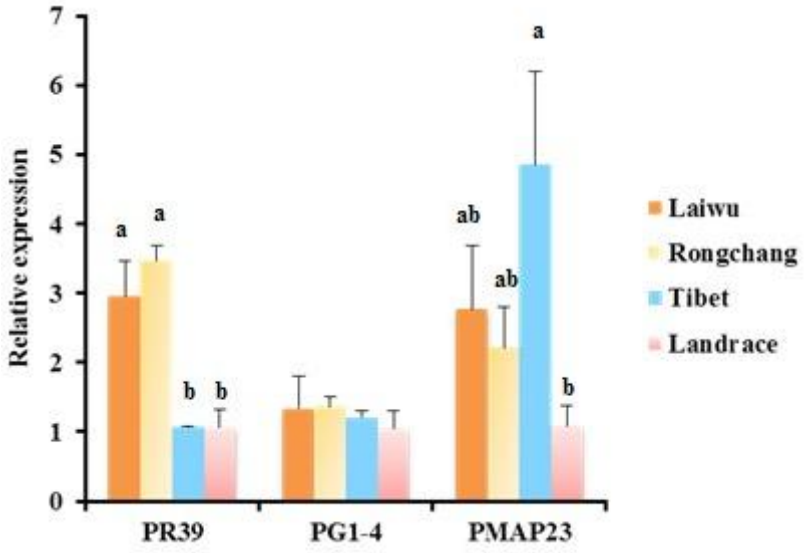


Fig. 22 Cathelicidin expression in Laiwu, Rongchang, Tibet and Landrace in bone marrow

Cathelicidin expression in intestinal tissues showed similar results in different pig breeds

3.4 Effect of *E.coli* K88 infection on AMPs expression in Jinhua and Landrace piglets

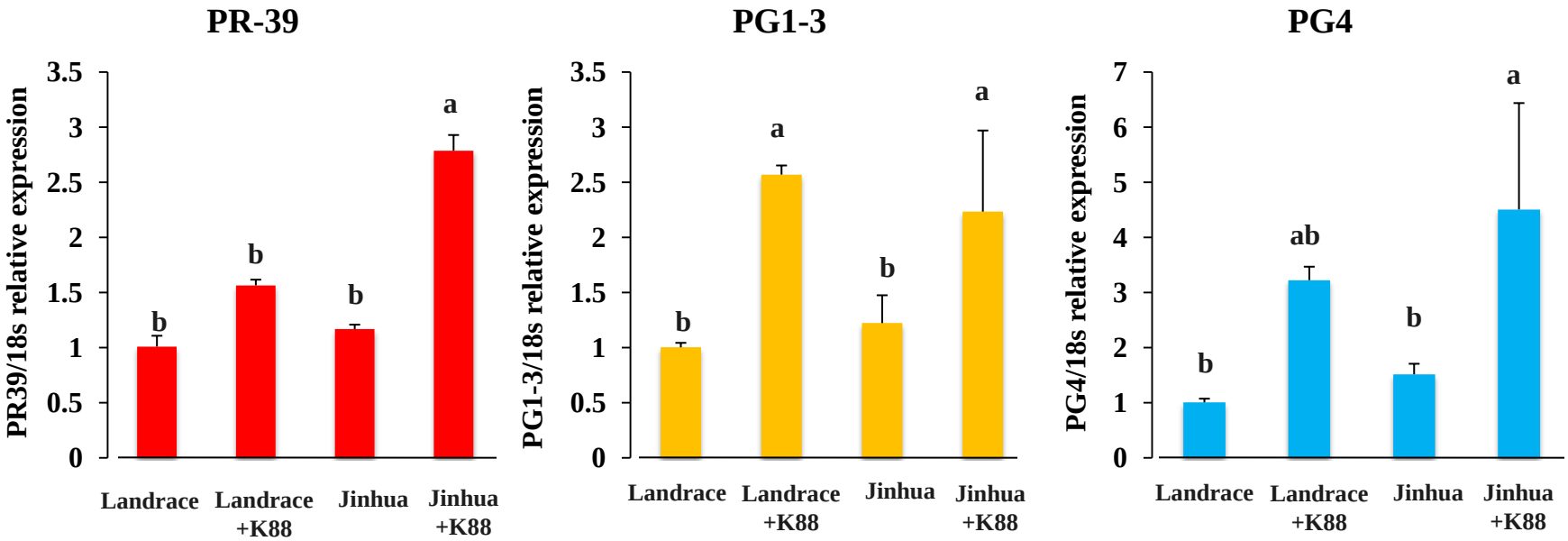


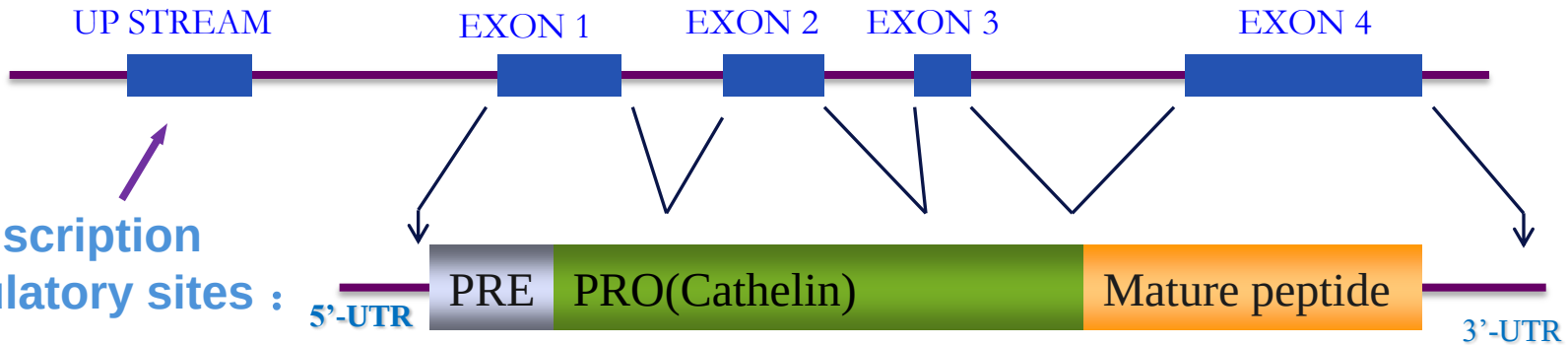
Fig. 23 Effect of *E.coli* K88 infection on AMPs expression in Jinhua and Landrace piglets

Infection with *E.coli* K88 significantly increased cathelicidin expression in Jinhua pigs in bone marrow.

Jinhua pigs showed lower diarrhea rate than Landrace after infection with *E.coli* K88.

Regulation of porcine endogenous AMPs

Gene structure of AMPs and possible transcription regulatory sites (eg. mammalian cathelicidin)



Transcription regulatory sites：

LF（lactoferrin）

LPS（lipopolysacchride）

Sp1（zinc）

Ap-2（zinc）

NF-κB

NF- IL-6,
IL-6-RE,

……

Pig: **PR-39**

PG-1

Prophenin

PMAPs

……

Ramanathan et al., 2002

3.5 Effect of trace nutrients and bioactive factors on AMPs expression in weaning piglets

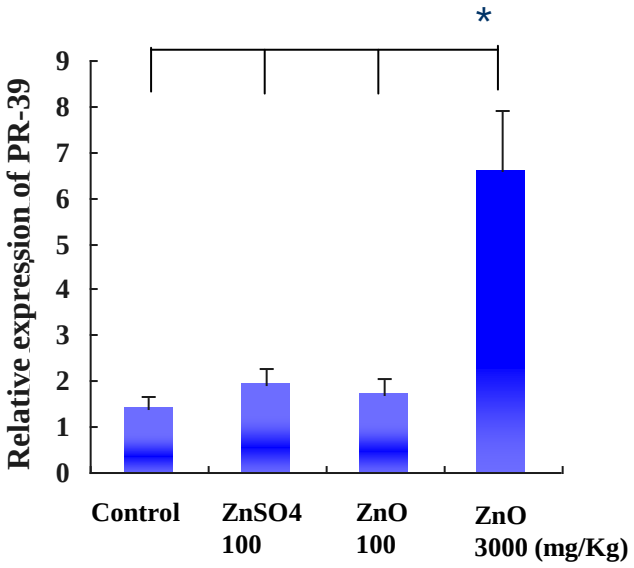


Fig. 24 Effect of ZnO on PR-39 expression

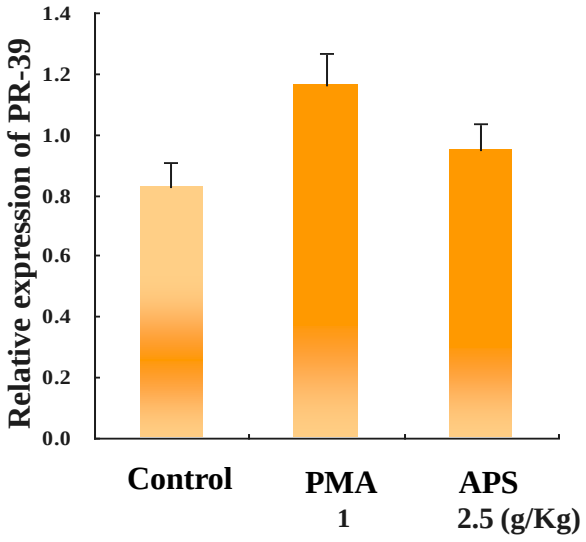


Fig. 25 Effect of polysaccharide on PR-39expression

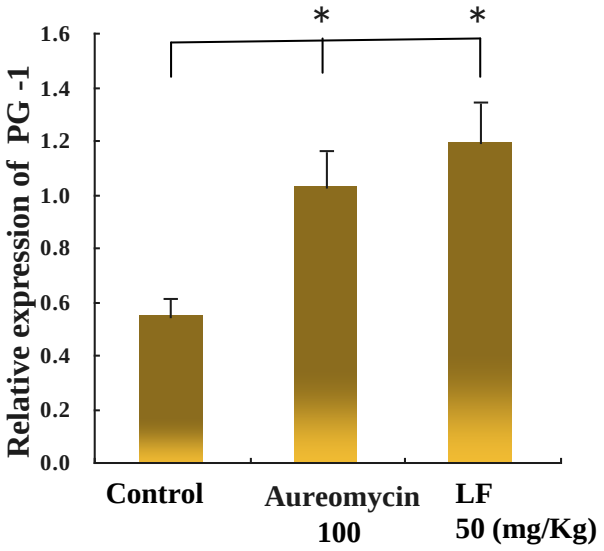


Fig. 26 Effect of lactoferrin on PG-1 expression

The utilization of trace nutrients(eg. zinc dioxide) and bioactive factors (eg. polysaccharide and lactoferrin) could modulate endogenous antimicrobial peptide expression in weaning piglets

Summary (3)

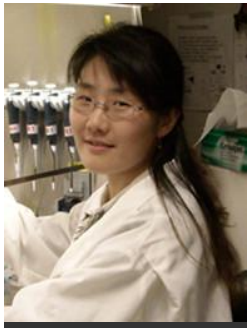
- **Expression of AMPs showed a developmental pattern and low expression in piglets. Chinese local pig breeds had higher AMPs expression compared to landrace.**
- **Lactoferrin, polysaccharides and zinc oxide could significantly improve AMPs expression in piglets, which provide a promising strategy to resolve the problems caused by weaning like diarrhea and antibiotics abuse.**

Implication

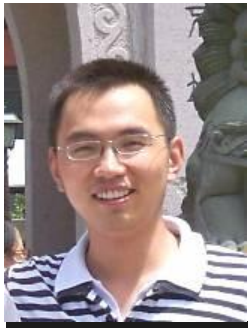
- China has abundant resources of AMPs, therefore, further study needs to be carried out.
- The antibacterial activity, cytotoxicity, mechanisms of animal-derived AMPs are variable. A great deal of screening work is urgently needed.
- AMPs with more potent activity and lower cytotoxicity will be obtained through screening and molecular design.
- The expression level of recombinant peptides needs to be improved dramatically in order to apply AMPs into animal production.
- More attention should be paid to how to enhance the expression of swine endogenous AMPs through nutritional regulation before their application.

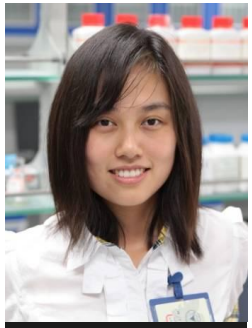
Acknowledgement

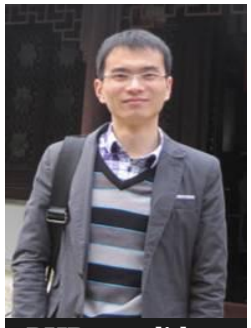
Hard work of


Dr. Feifei Han


Dr. Yifan Liu


Dr. Yonggang Xie


PHD. Candidate Yanhua Gao


PHD. candidate Chao Luan


PHD. Candidate Xi Xia


PHD. Candidate Haiwen Zhang

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Dr. Denis Groleau,

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National Science Fund for Distinguished Young Scholars(31025027)

National Natural Science Fund(C170105)

Research Group

Welcome to Zhejiang University !

Welcome to Hangzhou !

Oriental Capital of Leisure
City of Quality Life

Thanks for your attention!

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Research work

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