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# 韓國畜産學會 國際學術發表會

2026 Annual International Conference of KSAST

“축산 70년의 비전과 도약:  
인간, 동물, 환경이 함께 걷는  
지속가능한 축산 혁신”

Vision and Leap Forward of Livestock's 70 Years:  
Sustainable Innovation for Humans,  
Animals, and the Environment

제주국제컨벤션 센터 (ICC JEJU)

2026년 7월 8일(수)~10일(금)

- 주최/주관 : (사)한국축산학회, (사)한국가금학회, 농림축산식품부, 국립축산과학원, 축산관련단체 연합회
- 후원기관 : 한국과학기술단체총연합회, 제주특별자치도
- 후원업체 : 대한한돈협회, (사)전국한우협회, 한우자조금관리위원회, 서울우유협동조합, (주)우성사료, (주)이지홀딩스, (주)카길애그리퓨리나, BASF, 노보네시스 코리아, (주)모닝바이오, 우유자조금관리위원회, 제일사료 축산기술연구소, (주)팜스코, De Heus Korea, 농협경제지주, 낙농진흥회, 농축산용미생물산업육성지원센터, (주)다운, (주)선진, (주)솔로몬, 우리와(주), 유진바이오, 축산환경관리원, (주)파이지노믹스, (사)한국단미사료협회, (주)휘드베스트, 김유용 교수, 체리부로, (주)ACC, NH순한한우조합공동사업법인, 다산데이터, (주)마크로젠, (주)미래생명자원, 성우라이프사이언스, 에스엠티정보기술(주), (주)인프로, 정농바이오, (주)진바이오텍, 포스코리아, 한양사료주식회사, 한국반추미생물연구회, 달사랑 연구회, 고려비엔피, 나우피드, 대한사료(주), (주)대호, (주)도드람양돈서비스, (주)린도, 마리동물의학연구소, (주)솔튼바이오켄, 임실치즈&식품연구소, (주)티엔티리서치, 한국종축개량협회, 한국유가공협회, 전국낙농관련조합장협의회, 농심, 매일유업

(사) 한국 축 산 학 회

Korean Society of Animal Science and Technology



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# 학술대회 전체일정표

◆ 제주국제컨벤션 센터 (ICC JEJU)

●● 2026년 7월 8일 (수)

시간	장소	제주국제컨벤션 센터 (ICC JEJU)
11:00~		등록 및 접수 (3층 로비)
12:00~		포스터 부착 (3층 로비) * 주의: 포스터 부착 시간 엄수 (7/8, 12:00~17:00)
		<b>탐라홀 A (5층)</b>
13:00~13:30		개회사 : 이상석 (한국축산학회장) 환영사 : 민원기 (한국가금학회회장) 축 사 : 권오남 (한국과학기술단체총연합회회장) 축 사 : 이재식 (농림축산식품부축산정책국장) 기념사 : 조용민 (국립축산과학원장) 축 사 : 민경천 (한우자조금관리위원회위원장) 축 사 : 이기홍 (대한한돈협회장) 환영사 : 위성곤 (제주특별자치도지사) 축 사 : 안병우 (농협경제지주 축산경제 대표)
13:30~14:00		학회시상 및 학술대상 시상
14:00~14:50		<b>Plenary Lecture 1</b> 좌장: 김명후 교수
	Prof. Andrea Rosati (EAAP)	Prospects and Development Plans of European Animal Science
14:50~15:40		<b>Plenary lecture 2</b> 좌장: 장영달 교수
	김유용 교수 (서울대학교)	History of the KSAST and Future Development Directions of the Korean Livestock Industry
15:40~16:00		휴 식 (Coffee Break)
16:00~16:30		JAST 편집위원 회의 (302호)
16:00~17:00		한국가금학회 이사회 (304호)
		<b>기업 및 축산과학원 심포지엄&amp;워크숍</b>
14:00~18:00		축산과학원 반려동물전주기고도화 기술개발 공동연구사업 성과공유 워크숍 (301호)
15:00~18:00		가축 정밀영양사양 심포지엄: 축산분야 탄소중립을 위한 영양학적 접근 (한라홀 A, 3층)
16:00~18:00		팜스코 기업 심포지엄: 한돈 산업의 현재와 미래 (303호)
16:00~18:30		BASF 기업 심포지엄: Precision Enzyme Nutrition Unleashed (삼다홀 B, 3층)
		<b>탐라홀 B+C (5층)</b>
19:00~20:30		만찬

2026년 7월 9일 (목)

시간	장소 제주국제컨벤션 센터 (ICC JEJU)							
08:00~	등록 및 접수 (3층 로비)							
	한라홀 A+B (3층)							
08:30~09:20	Plenary Lecture 3 좌장: 서성원 교수							
	이준헌 교수 (충남대학교)			Animal Genetics, Past, Present and Future				
09:30~12:00	연구회 세션							
	낙농연구회 (삼다홀 A)	동물마이크로	반려동물영양		마연구회 (303호)	스마트축산		
		바이옴	연구회			빅데이터		
		연구회	(301호)				연구회	
		(삼다홀 B)						(401호)
가금학회 특강 및 정기총회 (202호)								
09:20~10:10	한국가금학회 개회식 및 오당학술상 특강							
10:10~11:10	한국가금학회 가금질병 세미나							
11:10~11:30	한국가금학회 정기총회							
	탐라홀 B+C (5층), 델리뷰 (4층)							
11:30~12:30	점심식사 & 정기총회							
	한라홀 A+B (3층)							
12:30~13:10	Plenary Lecture 4 좌장: 김종남 교수							
	Prof. Isaac Cann (University of Illinois Urbana-Champaign, USA)			Plant Fiber Digestion, an Animal Scientist's Journey from the Cow Rumen to the Human Gut				
	3층 로비							
13:10~14:30	포스터 발표 및 우수 포스터 심사							
14:30~16:00	학생 구두발표 I							
	단위영양 1 (삼다홀 A)	단위영양 2 (삼다홀 B)	단위영양 3 (301호)	반추영양 1 (303호)	동물생명공학1 (401호)	번식 및 생리 (402A호)	축산물 이용 및 가공 (402B호)	
	좌장: 박상우 교수	좌장: 이지환 교수	좌장: 성정열 교수	좌장: 오준표 교수	좌장: 황정호 교수	좌장: 박원형 교수	좌장: 서진규 교수	
16:00~16:30	휴식 (Coffee Break)							
	기업 심포지엄 및 축산과학원 워크숍							
13:00~17:00	KOICA (한국국제협력단) 축산분야 국제협력 심포지엄: 한국 축산의 국제사회 역할 전환: 수혜국에서 기여국으로 (400호)							

시간 \ 장소	제주국제컨벤션 센터 (ICC JEJU)					
13:10~15:10	축산과학원 가금연구센터 포럼 (202호)					
13:10~17:30	신농업기후변화대응체계구축사업 축산분야 워크숍 (201A호)					
14:00~16:00	카길 기업 심포지엄 (201B호)					
16:30~18:30	농촌진흥청 2026년 신규 공동연구개발사업 사업목표 달성을 위한 축산학회 연계 워크숍 (402B호)					
	가금학회 세션 1 (202호)					
15:10~16:20	한국가금학회 전문가 특강					
16:30~18:10	한국가금학회 차세대학술상 및 신진가금학자 특강					
	학생 구두발표 II					
16:30~18:15	단위영양 4 (삼다홀 A)	단위영양 5 (삼다홀 B)	유전, 육종 및 반추영양 기타 (301호)	반추영양 2 (303호)	동물생명공학 2 (401호)	환경 및 축산 기타 (402A호)
	좌장: 박상우 교수	좌장: 이지환 교수	좌장: 박종은 교수	좌장: 김원섭 교수	좌장: 황정호 교수	좌장: 이동준 교수
	오션뷰 (5층)					
18:30~20:00	기업과의 소연회					

2026년 7월 10일 (금)

시간	장소	제주국제컨벤션 센터 (ICC JEJU)	
08:00~		등록 및 접수 (3층 로비)	
		한라홀 (3층)	
08:50~09:30		Plenary Lecture 5 좌장: 공창수 교수	
	김현범 교수 (단국대학교)	Understanding the Diversity and Roles of the Pig Gut Microbiome	
09:40~11:40		중견 & 신진과학자 세션	
		영양사료 및 환경복지 (201호) 좌장: 장재철 교수	
	전중환 (강원대학교)	Philosophy of Animal Welfare and Application of Animal Behavior	
	장영달 (University of Georgia)	The Role of Vitamin D in the Antioxidant Status of Pigs	
	성정열 (부산대학교)	Amino Acid Nutrition in Pigs and Chickens	
		유전/육종/생명공학 (202호) 좌장: 임규상 교수	
	김준모 (중앙대학교)	PRRSV Functional Genomics: Past Decade and Future Perspectives	
	박원형 (충북대학교)	From Livestock Environmental Exposure to Cellular Dysfunction: Mechanistic Toxicology in Porcine Cells	
	황정호 (건국대학교)	Current Research Trend in Xenotransplantation	
		축산물 가공이용 및 축산환경 (203호) 좌장: 송수연 교수	
	정사무엘 (충남대학교)	Processing Strategies to Improve Animal Protein Digestibility for Age-Specific Customization	
	김종규 (Michigan State University)	Heat Stress and Marbling Development in Beef Cattle	
	이동준 (전남대학교)	From Waste to Resources: Multi-Pathway Approaches for Livestock Waste Resource Recovery and Greenhouse Gas Mitigation	
			가금학회 세션 2 (삼다홀 A, 3층)
9:50~12:00		한국가금학회 구두발표 및 시상식	

시간	장소 제주국제컨벤션 센터 (ICC JEJU)	
	한라홀 (3층)	
11:40~12:00	시상 및 폐회식 준비	
12:00~12:50	시상 및 폐회식	
	한국반추위미생물연구회 창립 30주년 기념 심포지엄 (삼다홀, 3층)	
14:00~14:20	등록 (Registration)	
14:20~14:30	개회 / 회장 인사 (Welcome Address by the President)	
14:30~15:20	Prof. Isaac Cann (University of Illinois Urbana-Champaign, USA)	Plant Cell Wall Degradation Strategies of Major Rumen Bacteria
15:30~16:20	Prof. Satoshi Koike (Hokkaido University, Japan)	From Early Feeding to Methane Control: Rumen Microbiota's Role in Ruminant Health and Productivity
16:20~17:10	Prof. Jakyem Seo (Pusan National University, Korea)	Hanwoo (beef) Industry in South Korea: Challenges and Solutions
	한국반추위미생물연구회 창립 30주년 기념식 (삼다홀, 3층)	
17:30~17:50	개회사 / 축하 (Anniversary Ceremony)	
17:50~18:20	Prof. Myung-gi Baik (Former President, KSRFS)	한국반추위미생물연구회 창립 30주년: 성과와 과제 Celebrating 30 Years of KSRFS: Achievements and Challenges
18:20~20:00	Banquet	

시간		07월 08일					07월 09일					07월 10일											
시간		ICC 5층		ICC 3층			ICC 5층		ICC 3층			ICC 4층		ICC 2층			ICC 3층		ICC 2층				
시간		탈라	탈라B	탈라C	301	302	303	탈라B	탈라A	탈라B	401	402A	402B	403	202	201A	201B	탈라B	탈라A	탈라B	201AB	202	203
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# [The Korean Society of Animal Science and Technology (KSAST) 70th Anniversary Annual Conference]

**Date:** July 8 (Wed) - 10 (Fri), 2026

**Place:** Jeju International Convention Center (ICC JEJU)

**Theme:** Vision and Leap Forward of Livestock's 70 Years: Sustainable Innovation for Humans, Animals, and the Environment

●● Wednesday, July 8, 2026

Time	Program	
11:00~	Registration (3F Lobby)	
12:00~	Poster mounting (3F Lobby) Poster mounting time must be observed (Jul 8, 12:00~17:00)	
<b>Tamna Hall A (5F)</b>		
13:00~13:30	Opening Address: Sang-Suk Lee (President, Korean Society of Animal Science and Technology) Welcome Address: Won-Ki Min (President, Korean Poultry Science Association) Congratulatory Address: Oh-Nam Kwon (President, Korea Federation of Science and Technology Societies) Congratulatory Address: Jae-Sik Lee (Director General, Livestock Policy Bureau, Ministry of Agriculture, Food and Rural Affairs) Commemorative Address: Yong-Min Cho (Director General, National Institute of Animal Science) Congratulatory Address: Kyung-Cheon Min (Chairman, Hanwoo Board) Congratulatory Address: Ki-Hong Lee (President, Korea Pork Producers Association) Welcome Address: Seong-gon Wi (Jeju Provincial Government) Congratulatory Address: Byung-Woo Ahn (CEO, NongHyup Agribusiness Group)	
13:30~14:00	Society Awards & Academic Grand Prize Ceremony	
<b>Plenary Lecture 1</b>		
14:00~14:50	Chair: Prof. Myunghoo Kim	
	Prof. Andrea Rosati (The European Federation of Animal Science)	Prospects and Development Plans of European Animal Science
<b>Plenary Lecture 2</b>		
14:50~15:40	Chair: Prof. Young Dal Jang	
	Prof. Yoo Yong Kim (Seoul National University)	History of the KSAST and Future Development Directions of the Korean Livestock Industry
15:40~16:00	Coffee Break	
16:00~16:30	JAST Editorial Board Meeting (Room 302)	
16:00~17:00	Korean Poultry Science Association Board Meeting (Room 304)	
<b>Corporate &amp; NIAS Symposia and Workshop</b>		
14:00~18:00	NIAS Workshop: Outcomes of the Joint Research Project on Full-Life-Cycle Companion Animal Technology Development (Room 301)	
15:00~18:00	Symposium on Precision Nutrition Feeding of Livestock (Halla Hall A, 3F)	
16:00~18:00	Farmsco Corporate Symposium: The Present and Future of the Korean Pork Industry (Room 303)	
16:00~18:30	BASF Korea Corporate Symposium: Precision Enzyme Nutrition Unleashed (Samda Hall B, 3F)	
<b>Tamna Hall B+C (5F)</b>		
19:00~20:30	Dinner Banquet	

●● Thursday, July 9, 2026

Time	Program						
08:00~	Registration (3F Lobby)						
	Halla Hall A+B (3F)						
08:30~09:20	Plenary Lecture 3 Chair: Prof. Seong-won Seo						
	Prof. Jun-heon Lee (Chungnam National University)				Animal Genetics: Past, Present and Future		
09:30~12:00	Research Society Sessions						
	Dairy Science Research Society (Samda Hall A)	Animal Microbiome Research Society (Samda Hall B)	Companion Animal Nutrition Research Society (Room 301)	Equine Research Society (Room 303)	Smart Livestock Big Data Research Society (Room 401)		
	Korean Poultry Science Association — Special Lectures & General Assembly (Room 202)						
09:20~10:10	Opening Ceremony of the Korean Society of Poultry Science & Odang Academic Award Lecture						
10:10~11:10	Korean Society of Poultry Science – Poultry Disease Seminar						
11:10~11:30	Korean Poultry Science Association General Assembly						
	Tamna Hall B+C (5F), Deli View (4F)						
11:30~12:30	Lunch & General Assembly						
	Halla Hall A+B (3F)						
12:30~13:10	Plenary Lecture 4 Chair: Prof. Jong Nam Kim						
	Prof. Isaac Cann (University of Illinois Urbana-Champaign, USA)				Plant Fiber Digestion, an Animal Scientist's Journey from the Cow Rumen to the Human Gut		
	3F Lobby						
13:10~14:30	Poster Presentations & Outstanding Poster Judging						
14:30~16:00	Student Oral Presentations I						
	Monogastric Nutrition 1 (Samda Hall A)	Monogastric Nutrition 2 (Samda Hall B)	Monogastric Nutrition 3 (Room 301)	Ruminant Nutrition 1 (Room 303)	Animal Biotechnology 1 (Room 401)	Reproduction & Physiology (Room 402A)	Livestock Product Utilization & Processing (Room 402B)
	Chair: Prof. Sangwoo Park	Chair: Prof. Jihwan Lee	Chair: Prof. Jung Yeol Sung	Chair: Prof. Joonpyo Oh	Chair: Prof. Jeong Ho Hwang	Chair: Prof. Wonhyoung Park	Chair: Prof. Jin-Kyu Seo
16:00~16:30	Coffee Break						

● Corporate Symposia & NIAS Workshop

Time	Place	Program
13:00~17:00	Room 400	KOICA (Korea International Cooperation Agency) International Cooperation Symposium in Animal Science Transforming the Global Role of Korean Animal Industry: K-Livestock — From Recipient to Contributor
13:10~15:10	Room 202	National Institute of Animal Science, Poultry Research Center Forum
13:10~17:30	Room 201A	Livestock-Sector Workshop on the New Agro-Climate Change Response System
14:00~16:00	Room 201B	Cargill Corporate Symposium
16:30~18:30	Room 402B	KSAST-RDA Joint Workshop for Achieving the Goals of the 2026 New Collaborative Research and Development Program

● Korean Poultry Science Association — Session 1 (Room 202)

Time	Program
15:10~16:20	Korean Poultry Science Association – Expert Special Lecture
16:30~18:10	Korean Poultry Science Association – Next-Generation Academic Award & Emerging Poultry Scientist Lecture

● Student Oral Presentations II

Time	Program					
	<b>Student Oral Presentations II</b>					
16:30~18:15	Monogastric Nutrition 4 (Samda Hall A)	Monogastric Nutrition 5 (Samda Hall B)	Genetics, Breeding & Ruminant Nutrition (Misc.) (Room 301)	Ruminant Nutrition 2 (Room 303)	Animal Biotechnology 2 (Room 401)	Environment & Animal Science (Misc.) (Room 402A)
	Chair: Prof. Sangwoo Park	Chair: Prof. Jihwan Lee	Chair: Prof. Jong-Eun Park	Chair: Prof. Won Seob Kim	Chair: Prof. Jeong Ho Hwang	Chair: Prof. Dong-Jun Lee
	<b>Ocean View (5F)</b>					
18:30~20:00	Networking Reception with Industry Partners					

●● Friday, July 10, 2026

Time	Program	
08:00~	Registration (3F Lobby)	
	<b>Halla Hall (3F)</b>	
08:50~09:30	<b>Plenary Lecture 5</b> Chair: Prof. Changsu Kong	
	Prof. Hyeun Bum Kim (Dankook University)	Understanding the Diversity and Roles of the Pig Gut Microbiome
09:40~11:40	<b>Mid-Career &amp; Early-Career Scientist Sessions</b>	
	<b>Nutrition, Feed &amp; Environmental Welfare (Room 201)</b> Chair: Prof. Jaecheol Jang	
	Jung Hwan Jeon (Kangwon National University)	Philosophy of Animal Welfare and Application of Animal Behavior
	Young Dal Jang (University of Georgia)	The Role of Vitamin D in the Antioxidant Status of Pigs
	Jung Yeol Sung (Pusan National University)	Amino Acid Nutrition in Pigs and Chickens
	<b>Genetics / Breeding / Biotechnology (Room 202)</b> Chair: Prof. Kyu-Sang Lim	
	Jun-Mo Kim (Chung-Ang University)	PRRSV Functional Genomics: Past Decade and Future Perspectives
	Wonhyoung Park (Chungbuk National University)	From Livestock Environmental Exposure to Cellular Dysfunction: Mechanistic Toxicology in Porcine Cells
	Jeong Ho Hwang (Konkuk University)	Current Research Trends in Xenotransplantation
	<b>Livestock Product Processing &amp; Environment (Room 203)</b> Chair: Prof. Sooyeon Song	
	Samooel Jung (Chungnam National University)	Processing Strategies to Improve Animal Protein Digestibility for Age-Specific Customization
	Jongkyoo Kim (Michigan State University)	Heat Stress and Marbling Development in Beef Cattle
	Dong-Jun Lee (Chonnam National University)	From Waste to Resources: Multi-Pathway Approaches for Livestock Waste Resource Recovery and Greenhouse Gas Mitigation
	<b>Korean Poultry Science Association — Session 2 (Samda Hall A, 3F)</b>	
	09:50~12:00	Korean Poultry Science Association – Oral Presentations & Awards Ceremony

	<b>Halla Hall (3F)</b>
11:40~12:00	Awards & Closing Ceremony Preparation
12:00~12:50	Awards & Closing Ceremony
	<b>Technical Tour (Tourist Sites on Jeju Island)</b>
13:00~	(For registered participants only)

● **Satellite Event: Korean Society of Rumen Function and Studies (KSRFS)  
30th Anniversary Commemorative Symposium**

Time	Program	
	<b>Samda Hall (3F)</b>	
14:00~14:20	Registration	
14:20~14:30	Opening / Welcome Address by the President	
14:30~15:20	Prof. Isaac Cann (University of Illinois Urbana-Champaign, USA)	Plant Cell Wall Degradation Strategies of Major Rumen Bacteria
15:30~16:20	Prof. Satoshi Koike (Hokkaido University, Japan)	From Early Feeding to Methane Control: Rumen Microbiota's Role in Ruminant Health and Productivity
16:20~17:10	Prof. Jakyoom Seo (Pusan National University, Korea)	Hanwoo (beef) Industry in South Korea: Challenges and Solutions
	<b>KSRFS 30th Anniversary Ceremony (Samda Hall, 3F)</b>	
17:30~17:50	Opening Remarks / Congratulatory Address (Anniversary Ceremony)	
17:50~18:20	Prof. Myung-gi Baik (Former President, KSRFS)	Celebrating 30 Years of KSRFS: Achievements and Challenges
18:20~20:00	Banquet	

## Poster Presentation

July 9 (Thursday), 13:10~14:30 (3F Lobby)

Section	Number	Poster No.
Monogastric Nutrition	80	PA26001 ~ PA26080
Ruminant Nutrition	78	PB26001 ~ PB26078
Animal Biotechnology	37	PC26001 ~ PC26037
Reproduction and Physiology	24	PD26001 ~ PD26024
Utilization and Processing of Livestock Products	19	PE26001 ~ PE26019
Genetic and Breeding	33	PF26001 ~ PF26033
Forage Science and Environment	28	PG26001 ~ PG26028

## Oral Presentation I

July 9 (Thursday), 14:30~16:00

Room	Section	Number	Poster No.
Samda Hall A	Monogastric Nutrition I	6	OA26001 ~ OA26006
Samda Hall B	Monogastric Nutrition II	6	OA26007 ~ OA26012
301	Monogastric Nutrition III	6	OA26013 ~ OA26017, OD26001
303	Ruminant Nutrition I	6	OB26001 ~ OB26006
401	Animal Biotechnology I	6	OC26001 ~ OC26006
402A	Reproduction and Physiology	6	OD26002 ~ OD26007
402B	Utilization and Processing of Livestock Products	6	OE26001 ~ OE26006

## Oral Presentation II

July 9 (Thursday), 16:30~18:15

Room	Section	Number	Poster No.
Samda Hall A	Monogastric Nutrition IV	6	OA26018 ~ OA26023
Samda Hall B	Monogastric Nutrition V	6	OA26024 ~ OA26029
301	Genetic, Breeding, and Other Ruminant Nutrition	6	OB26013 ~ OB26014 OD26008 OF26001 ~ OF26003
303	Ruminant Nutrition II	6	OB26007 ~ OB26012
401	Animal Biotechnology II	6	OC26007 ~ OC26012
402A	Environment and Other Animal Science Topics	7	OG26001 ~ OG26007

## 총 합 심 포 지 엄

2026년 7월 8일(수) 11:00~20:30

- 주 제: 축산 70년의 비전과 도약: 인간, 동물, 환경이 함께 걷는 지속가능한 축산 혁신  
Vision and Leap Forward of Livestock's 70 Years: Sustainable Innovation for Humans, Animals, and the Environment

시간	장소	제주국제컨벤션 센터 (ICC JEJU)
11:00~		등록 및 접수(3층 로비)
12:00~		포스터 부착 (3층 로비) * 주의: 포스터 부착 시간 엄수 (7/8, 12:00~17:00)
		<b>탐라홀 A (5층)</b>
13:00~13:30		개회사 : 이상석(한국축산학회) 환영사 : 민원기(한국가금학회) 축 사 : 권오남(한국과학기술단체총연합회) 축 사 : 이재식(농림축산식품부축산정책국장) 기념사 : 조용민(국립축산과학원장) 축 사 : 민경천(한우자조금관리위원회위원장) 축 사 : 이기홍(대한한돈협회장) 환영사 : 위성곤(제주특별자치도지사) 축 사 : 안병우(농협경제제주 축산경제 대표)
13:30~14:00		학회시상 및 학술대상 시상
14:00~14:50		<b>Plenary Lecture 1</b> 좌장: 김명후 교수
	Prof. Andrea Rosati (EAAP)	Prospects and Development Plans of European Animal Science
14:50~15:40		<b>Plenary lecture 2</b> 좌장: 장영달 교수
	김유용 교수 (서울대학교)	History of the KSAST and Future Development Directions of the Korean Livestock Industry
15:40~16:00		휴 식 (Coffee Break)
16:00~16:30		JAST 편집위원 회의 (302호)
16:00~17:00		한국가금학회 이사회 (304호)
		<b>기업 및 축산과학원 심포지엄&amp;워크숍</b>
14:00~18:00		축산과학원 반려동물전주기고도화 기술개발 공동연구사업 성과공유 워크숍 (301호)
15:00~18:00		가축 정밀영양사양 심포지엄: 축산분야 탄소중립을 위한 영양학적 접근 (한라홀 A, 3층)
16:00~18:00		팜스코 기업 심포지엄: 한돈 산업의 현재와 미래 (303호)
16:00~18:30		BASF 기업 심포지엄: Precision Enzyme Nutrition Unleashed (삼다홀 B, 3층)
		<b>탐라홀 B+C (5층)</b>
19:00~20:30		만찬

# 반려동물전주기고도화 기술개발 공동연구사업 성과공유 워크숍 (301호)

2026년 7월 8일(수) 14:00~18:00

● 주 제 : 반려동물전주기고도화 기술개발 공동연구사업 성과공유 워크숍

14:00~14:10	유동조 (국립축산과학원 생환부장)	인사 말씀
14:10~15:00	세션 I. 반려동물 기능성 사료개발 및 영양 연구	
14:10~14:20	박성권 (세종대학교)	국내산 축산물 활용 반려견 기능성 사료 및 안전성 증진기술 개발
14:20~14:30	이경우 (건국대학교)	신규 기능성 사료소재 개발 및 반려동물 맞춤형 건강개선 기능성 사료 개발
14:30~14:40	장현준 [(재)농축산용미생물 산업육성지원센터]	반려동물 사료소재별 주요 에너지원 체내 이용률 및 장내 미생물 군집 변화
14:40~14:50	송민호 (충남대학교)	반려동물 주요 품종별·연령별 영양소 이용성 평가 연구
14:50~15:00	조성호 [(사)농정연구센터]	반려동물 사료 기준 및 규격 제도 개선 연구
15:00~15:30	Coffee Break	
15:30~16:10	세션 II. 유전정보·세포자원을 활용한 반려동물 건강 연구	
15:30~15:40	이성림 (경상국립대학교)	반려동물 건강수명 연장을 위한 생물학적 나이 측정기술의 개발과 임상적 활용
15:40~15:50	김형석 [(주)페토바이오]	반려동물 건강검진 활성화를 위한 의료데이터 및 참조지표 활용방안
15:50~16:00	황태성 (경상국립대학교)	개 이첨판 폐쇄부전증의 진단 및 예후 평가를 위한 임상·유전체 통합 연구
16:00~16:10	이민국 (국립축산과학원)	반려견 줄기세포 유래인자의 국소염증 치료 기전 규명 및 활용 연구
16:10~16:30	세션 III. 반려동물 행동특성 연구	
16:10~16:20	양가영 (국립축산과학원)	반려동물 행동특성 평가 방법 및 시스템 개발
16:20~16:30	서동원 [(주)티엔티리써치]	반려견 공격행동 특성관련 유전인자 탐색
16:30~17:50	참석자	반려동물 중장기 연구전략 수립을 위한 종합토론
17:50~18:00	성필남 (동물복지과장)	마무리

## 2026년 가축 정밀영양사양 심포지엄 (한라홀 A, 3층)

2026년 7월 8일(수) 15:00~18:00

- 주 제 : 축산분야 탄소중립을 위한 영양학적 접근

사회: 강환구 연구관 (국립축산과학원)

1부 좌장: 김지혁 교수 (공주대학교)

2부 좌장: 이흥구 교수 (건국대학교)

14:00~15:00	참가자 등록	
15:00~15:10	조용민 (국립축산과학원 원장)	참석자 소개 인사 말씀 기념 촬영
15:10~15:35	홍승탁 사무관 (농식품부)	축산분야 탄소중립을 위한 사료정책 방향
15:35~16:00	유재홍 박사 (제일사료)	산란계 질소저감을 위한 사료산업 동향 및 연구
16:00~16:10	휴식	
16:10~16:35	김법균 교수 (건국대학교)	돼지 유래 온실가스에 대한 영양학적 관점
16:35~17:00	이성신 연구사 (국립축산과학원)	반추가축 메탄저감제 개발 연구 현황
17:00~17:10	종합토론 준비	
17:10~18:00	가축정밀영양과장	종합 토론 및 폐회 *탄소중립을 위한 영양학적 접근 및 연구 혁신 방안

## BASF 기업 심포지엄 (삼다홀 B, 3층)

2026년 7월 8일(수) 16:00~18:30

- 주 제 : Precision Enzyme Nutrition Unleashed

사회 : Nicholas Yu (BASF Animal Nutrition Korea)

15:40~16:00	Registration & Reception Participant check-in, networking, and seat arrangement	
16:00~16:05	Nicholas Yu (BASF Animal Nutrition Korea)	Opening & Seminar Introduction
16:05~16:25	Dr. Hyung-II Lee (Cargill MHS)	Practical application of Feed Enzymes
16:25~16:55	Prof. Jung-Min Heo (Chungnam National University)	Enzyme Matrix Values: Scientific Understanding, Challenges, and Future Perspectives
16:55~17:30	Dr. Ashley England (BASF Animal Nutrition)	Intelligent Enzyme Combinations: Converting Anti-Nutritional Factors into Value
17:30~18:05	Leon Hall (BASF Animal Nutrition)	Precision Enzyme Nutrition with NatuSynX Turning Enzyme Combinations into Profit
18:05~18:25	All Speakers	Q&A and Discussion
18:25~18:30	Nicholas Yu (BASF Animal Nutrition Korea)	Closing Remarks & Follow-up

## 세부 일정 (7월 9일)

### 총 합 심 포 지 업

2026년 7월 9일(목) 8:00~20:00

시간	장소	제주국제컨벤션 센터 (ICC JEJU)						
08:00~		등록 및 접수 (3층 로비)						
		한라홀 A+B (3층)						
08:30~09:20		Plenary Lecture 3 좌장: 서성원 교수						
		이준헌 교수 (충남대학교)			Animal Genetics, Past, Present and Future			
09:30~12:00		연구회 세션						
		낙농연구회 (삼다홀 A)	동물마이크로 바이옴 연구회 (삼다홀 B)	반려동물영양 연구회 (301호)	마연구회 (303호)	스마트축산 빅데이터 연구회 (401호)		
		가금학회 특강 및 정기총회 (202호)						
09:20~10:10		한국가금학회 개최식 및 오당학술상 특강						
10:10~11:10		한국가금학회 가금질병 세미나						
11:10~11:30		한국가금학회 정기총회						
		탐라홀 B+C (5층), 델리뷰 (4층)						
11:30~12:30		점심식사 & 정기총회						
		한라홀 A+B (3층)						
12:30~13:10		Plenary Lecture 4 좌장: 김종남 교수						
		Prof. Isaac Cann (University of Illinois Urbana-Champaign, USA)			Plant Fiber Digestion, an Animal Scientist's Journey from the Cow Rumen to the Human Gut			
		3층 로비						
13:10~14:30		포스터 발표 및 우수 포스터 심사						
		학생 구두발표 I						
14:30~16:00		단위영양 1 (삼다홀 A)	단위영양 2 (삼다홀 B)	단위영양 3 (301호)	반추영양 1 (303호)	동물생명공학1 (401호)	번식 및 생리 (402A호)	축산물 이용 및 가공 (402B호)
		좌장: 박상우 교수	좌장: 이지환 교수	좌장: 성정열 교수	좌장: 오준표 교수	좌장: 황정호 교수	좌장: 박원형 교수	좌장: 서진규 교수
16:00~16:30		휴식 (Coffee Break)						

시간 \ 장소	제주국제컨벤션 센터 (ICC JEJU)					
	기업 심포지엄 및 축산과학원 워크숍					
13:00~17:00	KOICA (한국국제협력단) 축산분야 국제협력 심포지엄: 한국 축산의 국제사회 역할 전환: 수혜국에서 기여국으로 (400호)					
13:10~15:10	축산과학원 가금연구센터 포럼 (202호)					
13:10~17:30	신농업기후변화대응체계구축사업 축산분야 워크숍 (201A호)					
14:00~16:00	카길 기업 심포지엄 (201B호)					
16:30~18:30	농촌진흥청 2026년 신규 공동연구개발사업 사업목표 달성을 위한 축산학회 연계 워크숍 (402B호)					
	가금학회 세션 1 (202호)					
15:10~16:20	한국가금학회 전문가 특강					
16:30~18:10	한국가금학회 차세대학술상 및 신진가금학자 특강					
	학생 구두발표 II					
16:30~18:15	단위영양 4 (삼다홀 A)	단위영양 5 (삼다홀 B)	유전, 육종 및 반추영양 기타 (301호)	반추영양 2 (303호)	동물생명공학 2 (401호)	환경 및 축산 기타 (402A호)
	좌장: 박상우 교수	좌장: 이지환 교수	좌장: 박종은 교수	좌장: 김원섭 교수	좌장: 황정호 교수	좌장: 이동준 교수
	오션뷰 (5층)					
18:30~20:00	기업과의 소연회					

# 한국축산학회 산하 연구회 행사

2026년 7월 9일(목) 9:30~12:00

## 1. 낙농연구회 (삼다홀 A)

- 주 제 : K-낙농의 현재와 과제

좌장 : 강상기 부회장 (서울대학교 교수)

등록 / 개회식		
진행 : 서자겸 상무이사 (부산대학교 교수)		
09:30~09:45	등 록	
09:45~10:00	개회사 : 서성원 회장 (충남대학교 교수) 축사 : 김경규 회장 (낙농진흥회)	
초 청 강 연		
10:00~10:30	오준표 교수 (서울대학교)	낙농 연구 최신 동향
10:30~11:00	한주석 팀장 (낙농진흥회)	전국단위 집유체계 구축을 통한 국내 낙농산업 구조개선 방안
11:00~11:30	정순태 총괄 (주)제주우유)	제주 낙농 산업의 당면과제와 발전 방안
11:30~	폐 회	

## 2. 동물마이크로바이옴연구회 (삼다홀 B)

- 주 제 : 안전하고 지속가능한 동물생산을 위한 반추위 마이크로바이옴 혁신 전략

Chairperson : Prof. Sejong Oh (Chonnam National University)

9:00~9:30	Registration	
연 사 및 제 목		
09:30~10:00	Prof. Jong Nam Kim (Dongseo University)	Modulation of Rumen Microbiome and Enteric Methane Reduction by SCOPY-based Probiotics: From <i>In Vitro</i> Fermentation to TMF Application
10:00~10:30	Prof. Myunghoo Kim (Seoul National University)	Technologies to Address Climate Change and Improve the Health of Ruminants by Utilizing the Microbiome and Metabolome
10:30~11:00	Prof. Min-Jin Kwak (Kookmin University)	Characterization of Core Microbiota and Methane-Related Functional Genes Associated with Methane Emissions and Growth Performance in Cattle
11:00~11:30	Prof. Younghoon Kim (Seoul National University)	Rumen-Derived Next Generation Probiotics for Sustainable Bioplastic Production and Microplastic Toxicity Mitigation

### 3. 반려동물영양연구회 (301호)

- 주 제 : 차세대 펫푸드 R&D 패러다임: 글로벌 트렌드부터 정책 및 연구 동향

좌장 : 김기현 교수 (국립순천대학교)

10:00~10:15	등 록	
10:15~10:20	개 회 / 회장인사 / 안내말씀	
연 사 및 제 목		
10:20~10:40	소경민 농업연구관 (국립축산과학원)	펫푸드 글로벌 트렌드와 한국 R&D 정책, 산업의 나아갈 길
10:40~11:10	송광영 교수 (대구한의대학교)	단위축산동물과 반려동물의 질병 및 영양에 대한 비교 분석
11:10~11:40	박근현 책임연구원 ((주)우리와)	반려견의 식이역반응, 아토피 피부염 증상 완화를 위한 영양학적 관리
11:40~12:00	종합토론 및 폐회	

### 4. 마연구회 (303호)

- 주 제 : 국내 말(馬)산업 분야 연구 동향

좌장 : 윤민중 교수 (경북대학교)

9:00~9:30	등 록	
9:30~9:40	개 회 / 회장인사 / 안내말씀	
연 사 및 제 목		
9:40~10:10	오정섭 석사과정생 (제주대학교)	말 장제 현장의 안전·복지 향상을 위한 한국형 하이브리드 모델 설계
10:10~10:40	최재영 박사 (난지축산연구센터)	난지축산연구센터 말 연구 현황
10:40~11:10	정용욱 박사과정생 (경북대학교)	Neurophysiological and Emotional Effects of Equine-Assisted Activities
11:10~11:30	종합토론 및 폐회	

5. 스마트축산빅데이터연구회 (401호)

- 주 제 : 축산데이터환류와 AI전환 전략

좌장 : 김준모 교수 (중앙대학교)

10:00~10:10	등 록	
10:10~10:15	개 회 / 회장인사 / 안내말씀	
연 사 및 제 목		
10:15~10:35	Jame Koltes 교수 (Iowa State University)	Data Reuse in Agricultural Genomics Research
10:35~11:05	양희재 대표 ((주)코쿤)	탄자니아 낙농산업 저탄소화 역량강화를 위한 BIT기반 선진 축산 생태계 구축 전략
11:05~11:35	박종은 교수 (제주대학교)	기후변화 대응 동물 오믹스 빅데이터 활용 연구
11:35~11:55	채병호 박사 (전북대학교)	인공지능 기반 젓소 공태우 탐지 안전망
11:40~12:00	종합토론 및 폐회	

## 한국가금학회 개최식 및 오당학술상 특강 (202호)

2026년 7월 9일(목) 09:20~10:10

사회 : 이경우 교수 (건국대학교)

09:20~09:30	개회식	
09:30~10:10	오당학술상 특강	
	장형관 교수 (전북대학교)	Herpesvirus를 이용한 동물용 백신 개발 기술의 발전과 응용

## 한국가금학회 가금질병 세미나 (202호)

2026년 7월 9일(목) 10:10~11:10

좌장 : 허문 과장 (농림축산검역본부)

10:10~10:40	장일 연구사 (농림축산검역본부)	Dynamics of the Emerging Genogroup of Infectious Bursal Disease Virus Infection in Broiler Farms in South Korea
10:40~11:10	강성일 연구사 (농림축산검역본부)	해양미생물 기반 동물용 항생제 대체제의 활용 가능성

## 한국가금학회 정기총회 (202호)

2026년 7월 9일(목) 11:10~11:30

사회 : 이경우 교수 (건국대학교)

11:10 ~ 11:30	한국가금학회 정기총회
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## 축산과학원 가금연구센터 포럼 (202호)

2026년 7월 9일(목) 13:10~15:10

좌장 : 김경운 센터장 (국립축산과학원 가금연구센터)

13:10~13:20	좌장 및 연사 소개	
13:20~13:40	추효준 박사 (국립축산과학원)	토종닭 순계 개량 및 품종 개발 현황
13:40~14:00	이준헌 교수 (충남대학교)	토종닭 유전체 연구 현황 및 최신 연구 동향
14:00~14:20	김영준 부장 (한국토종닭 협회)	국내 토종닭 산업 현황 및 발전 방향
14:20~14:40	신소연 사무관 (농림축산식품부)	토종닭 관련 정책 방향 및 제언
14:40~15:10	종합 토론	

## 한국가금학회 전문가 특강 (202호)

2026년 7월 9일(목) 15:10~16:20

좌장 : 홍영호 교수 (중앙대학교)

15:10~15:40	김종준 사무국장 (계란자조금관리위원회)	대한민국 미래자산 갈색 반도체 계란
15:40~16:00	김명섭 수의사 (HIPRA)	국내 IB 발생현황 및 유전자형 분류체계
16:00~16:20	최수원 수의사 (한국엘랑코동물약품)	유럽 식중독 살모넬라 관리 사례

## 한국가금학회 차세대학술상 및 신진가금학자 특강 (202호)

2026년 7월 9일(목) 16:30~18:10

좌장 : 강민 교수 (전북대학교)

### 한국가금학회 차세대학술상 특강

16:30~16:50	임천익 박사 (국립축산과학원)	하절기 유정란 열 자극을 통한 후성유전학 기반 고온내성 육계 생산 기술
16:50~17:10	유명환 소장 (한국친환경축산연구소)	Nutritional Strategies for Improving Alternative Feedstuffs in Poultry via Dietary Supplements: Potnetial Role of Physiological and Metabolic Pathways

### 한국가금학회 신진가금학자 특강

17:10~17:30	배해득 박사 (전북대학교)	국외 고병원성 조류인플루엔자(HPAI) 대응 동향 및 백신 개발 현황
17:30~17:50	송승언 박사 (카브)	파라믹소바이러스 벡터 기반 저병원성조류인플루엔자 생독백신의 개발 및 사독백신 병용 효능 평가
17:50~18:10	이아란 교수 (건국대학교 동물자원연구센터)	사슬 길이에 따른 폴리인산염 급여가 가금의 장 건강 및 장내 마이크로바이옴에 미치는 영향

# KOICA (한국국제협력단) 축산분야 국제협력 심포지엄 (400호)

2026년 7월 9일(목) 13:00~17:00

- 주 제 : 한국 축산의 국제사회 역할 전환: K축산 - 수혜국에서 기여국으로 (글로벌 협력축산과 지속가능 축산)

사회: 신동현 교수 (전북대학교)  
 1부 좌장: 황성구 교수 (한경국립대학교)  
 2부 좌장: 김수기 교수 (건국대학교)

13:00~13:10	이상석 한국축산학회 회장	개회 및 세션 소개
13:10~13:40	김경훈 교수 (서울대학교)	라오스 낙농교육 기반 구축과 축산 고등교육 협력
13:40~14:10	김수기 교수 (건국대학교)	베트남 국립농업대학교 축산고등교육 기반 강화 및 전문인력 양성
14:10~14:40	남인식 교수 (한경국립대학교)	몽골 생명과학대학교 산학 연계형 고등교육 역량강화 사업 구성과 성과
14:40~15:10	서강석 교수 (국립순천대학교)	아시아에서 아프리카까지 축산 개발 협력
15:10~15:30	네트워크 브레이킹	
15:30~16:00	이학교 교수 (전북대학교)	아시아 동물산업 특화 전문인력 양성사업 기반의 지속가능한 상생 발전 방안
16:00~16:30	황성구 교수 (한경국립대학교)	개발도상국 ODA 사업의 성공전략과 지속가능성 확보 방안
16:30~17:00	참석자 전체	종합토론
17:00~	폐회 및 기념촬영	

## 신농업기후변화대응체계구축사업 축산분야 워크숍 (201A호)

2026년 7월 9일(목) 13:10~17:30

- 주 제 : 신농업기후변화대응체계구축사업 축산분야 워크숍

13:10~13:30	허정민 교수 (충남대학교)	고온환경에 따른 가금산물(계란, 계육)의 신선도 및 품질 저하 방지기술 개발
13:30~13:50	이경우 교수 (건국대학교)	닭의 동물복지 사육 시 고온기 생산성 저하 방지 기술 개발
13:50~14:10	하태환 교수 (충남대학교)	이상기상에 따른 가축의 고온스트레스 피해 경감기술 개발
14:10~14:40	Coffee Break	
14:40~15:00	장선식 연구관 (국립축산과학원)	고온스트레스 저감형 한우사양 프로그램 및 영양물질 첨가제 개발
15:00~15:20	박중훈 교수 (서울대학교)	기후변화 대응 고온기 한우 번식 효율 증진 기술 개발
15:20~15:40	장재철 교수 (경상국립대학교)	고온기 대비 돼지 번식 및 사료섭취량 저하 방지기술 개발
15:40~16:10	Coffee Break	
16:10~16:30	김진수 교수 (강원대학교)	고온기 번식능력 증진을 위한 모든 영양소 이용효율 증진 첨가제 활용기술 개발
16:30~16:50	김명후 교수 (서울대학교)	고온기 젖소의 스트레스 개선 조건 구명 및 생산성 향상 기술 개발
16:50~17:10	김대현 교수 (전남대학교)	기후변화에 따른 하절기 젖소의 번식능력 향상 기술 개발
17:10~17:30	최용준 교수 (한경대학교)	기후변화에 따른 축종별 생산성 실태조사 및 영향취약성 평가(2단계)

참고 : 과제 당 20분 발표 (15분 발표 후 5분 질의응답)

## 카길 기업 심포지엄 (201B호)

2026년 7월 9일(목) 14:00~16:00

- 주 제 : Dietary Strategy and Rearing Physiology as Drivers of Laying Persistency, Egg Production Curve Dynamics, and Sustainability in Modern Layer Systems

사회: 임태정 (Cargill MHS Category manager)  
통역: 신지은 (Cargill Poultry Category Manager)

14:00~15:40	Alexander De Leon (Cargill Global Technology Advisor – Poultry)	Dietary Strategy and Rearing Physiology as Drivers of Laying Persistency, Egg Production Curve Dynamics, and Sustainability in Modern Layer Systems
15:40~16:00		Q&A

## 농촌진흥청 2026년 신규 공동연구개발사업 사업목표 달성을 위한 축산학회 연계 워크숍 (402B호)

2026년 7월 9일(목) 16:30~18:30

- 주 제 : '26년 신규 공동연구사업 목표달성을 위한 연구추진 방향 공유 및 '28년 신규 연구사업 기획을 위한 전문가 의견 수렴

### ① 가축 생산비 절감 정밀사양 기술 고도화('26~'30)

16:30~16:40	등록, 내외빈 소개 및 사진 촬영
16:40~17:00	(가축생산비 절감) 사업 구성, 수행 및 성과관리 계획 설명
17:00~17:15	중간평가 대응 전략목표 및 성과지표(전략계획서) 안내

### ② 축산자원 활용 탄소중립 바이오 융합기술 개발('26~'30)

17:15~17:35	(축산자원활용탄소중립) 사업 구성, 수행 및 성과관리 계획 설명
17:35~17:50	중간평가 대응 전략목표 및 성과지표(전략계획서) 안내
17:50~18:30	2028년 신규 연구사업 기획을 위한 현장 의견수렴

## 포스터발표회

2026년 7월 9일(목) 13:10~14:30 (3층 로비)

분 야	편 수	포 스텐 NO.
단위영양	80	PA26001 ~ PA26080
반추영양	78	PB26001 ~ PB26078
동물생명공학	37	PC26001 ~ PC26037
번식 및 생리	24	PD26001 ~ PD26024
축산물 이용 및 가공	19	PE26001 ~ PE26019
유전 및 육종	33	PF26001 ~ PF26033
초지 및 환경	28	PG26001 ~ PG26028

## 구두발표회 I

2026년 7월 9일(목) 14:30~16:00

※ 발표자 1인당 10분 발표 / 5분 질의 및 응답

장 소	분 야	편 수	구두발표 NO.
삼다홀 A	단위영양 1	6	OA26001 ~ OA26006
삼다홀 B	단위영양 2	6	OA26007 ~ OA26012
301	단위영양 3	6	OA26013 ~ OA26017, OD26001
303	반추영양 1	6	OB26001 ~ OB26006
401	동물생명공학 1	6	OC26001 ~ OC26006
402A	번식 및 생리	6	OD26002 ~ OD26007
402B	축산물 이용 및 가공	6	OE26001 ~ OE26006

## 구두 발표회 II

2026년 7월 9일(목) 16:30~18:15

※발표자 1인당 10분 발표 / 5분 질의 및 응답

장 소	분 야	편 수	구두발표 NO.
삼다홀 A	단위영양 4	6	OA26018 ~ OA26023
삼다홀 B	단위영양 5	6	OA26024 ~ OA26029
301	유전, 육종 및 반추영양 기타	6	OB26013 ~ OB26014 OD26008 OF26001 ~ OF26003
303	반추영양 2	6	OB26007 ~ OB26012
401	동물생명공학 2	6	OC26007 ~ OC26012
402A	환경 및 축산 기타	7	OG26001 ~ OG26007

## 세부 일정 (7월 10일)

### 총 합 심 포 지 엄

2026년 7월 10일(금) 8:00~20:00

시간	장소	제주국제컨벤션 센터 (ICC JEJU)	
08:00~		등록 및 접수 (3층 로비)	
		한라홀 (3층)	
08:50~09:30		Plenary Lecture 5 좌장: 공창수 교수	
	김현범 교수 (단국대학교)	Understanding the Diversity and Roles of the Pig Gut Microbiome	
09:40~11:40		중견 & 신진과학자 세션	
		영양사료 및 환경복지 (201호) 좌장: 장재철 교수	
		전중환 (강원대학교)	Philosophy of Animal Welfare and Application of Animal Behavior
		장영달 (University of Georgia)	The Role of Vitamin D in the Antioxidant Status of Pigs
		성정열 (부산대학교)	Amino Acid Nutrition in Pigs and Chickens
		유전/육종/생명공학 (202호) 좌장: 임규상 교수	
		김준모 (중앙대학교)	PRRSV Functional Genomics: Past Decade and Future Perspectives
		박원형 (충북대학교)	From Livestock Environmental Exposure to Cellular Dysfunction: Mechanistic Toxicology in Porcine Cells
		황정호 (건국대학교)	Current Research Trend in Xenotransplantation
		축산물 가공이용 및 축산환경 (203호) 좌장: 송수연 교수	
		정사무엘 (충남대학교)	Processing Strategies to Improve Animal Protein Digestibility for Age-Specific Customization
		김종규 (Michigan State University)	Heat Stress and Marbling Development in Beef Cattle
		이동준 (전남대학교)	From Waste to Resources: Multi-Pathway Approaches for Livestock Waste Resource Recovery and Greenhouse Gas Mitigation

장소 시간	제주국제컨벤션 센터 (ICC JEJU)	
	가금학회 세션 2 (삼다홀 A, 3층)	
9:50~12:00	한국가금학회 구두발표 및 시상식	
	한라홀 (3층)	
11:40~12:00	시상 및 폐회식 준비	
12:00~12:50	시상 및 폐회식	
	한국반추위미생물연구회 창립 30주년 기념 심포지엄 (삼다홀, 3층)	
14:00~14:20	등록 (Registration)	
14:20~14:30	개회 / 회장 인사 (Welcome Address by the President)	
14:30~15:20	Prof. Isaac Cann (University of Illinois Urbana-Champaign, USA)	Plant Cell Wall Degradation Strategies of Major Rumen Bacteria
15:30~16:20	Prof. Satoshi Koike (Hokkaido University, Japan)	From Early Feeding to Methane Control: Rumen Microbiota's Role in Ruminant Health and Productivity
16:20~17:10	Prof. Jakyom Seo (Pusan National University, Korea)	Hanwoo (beef) Industry in South Korea: Challenges and Solutions
	한국반추위미생물연구회 창립 30주년 기념식 (삼다홀, 3층)	
17:30~17:50	개회사 / 축사 (Anniversary Ceremony)	
17:50~18:20	Prof. Myung-gi Baik (Former President, KSRFS)	한국반추위미생물연구회 창립 30주년: 성과와 과제 Celebrating 30 Years of KSRFS: Achievements and Challenges
18:20~20:00	Banquet	

## 증견 & 신진 과학자 세션

2026년 7월 10일(금) 9:40~11:40

### 1. 영양사료 및 환경복지 (201A+B호)

좌장: 장재철 교수		
시간	연사	제목
09:40~10:20	전중환 (강원대학교)	Philosophy of Animal welfare and Application of Animal behavior
10:20~11:00	장영달 (University of Georgia)	The Role of Vitamin D in the Antioxidant Status of Pigs
11:00~11:40	성정열 (부산대학교)	Amino Acid Nutrition in Pigs and Chickens

### 2. 유전/육종/생명공학 (202A+B호)

좌장: 임규상 교수		
시간	연사	제목
09:40~10:20	김준모 (중앙대학교)	PRRSV Functional Genomics: Past Decade and Future Perspectives
10:20~11:00	박원형 (충북대학교)	From Livestock Environmental Exposure to Cellular Dysfunction: Mechanistic Toxicology in Porcine Cells
11:00~11:40	황정호 (건국대학교)	Current Research Trend in Xenotransplantation

### 3. 축산물 가공이용 및 축산환경 (203호)

좌장: 송수연 교수		
시간	연사	제목
09:40~10:20	정사무엘 (충남대학교)	Processing Strategies to Improve Animal Protein Digestibility for Age-Specific Customization
10:20~11:00	김종규 (Michigan State University)	Heat Stress and Marbling Development in Beef Cattle
11:00~11:40	이동준 (전남대학교)	From Waste to Resources: Multi-Pathway Approaches for Livestock Waste Resource Recovery and Greenhouse Gas Mitigation

## 발표논문시상식 및 폐회식

- ▶ 일 시 : 2026년 7월 10일(금) 12:00
- ▶ 장 소 : 한라홀 (3층)
- ▶ 시 상 : 이상석 한국축산학회장
- ▶ 대 상 : 전 회원 및 수상자

※ 구두발표 및 포스터 우수 발표자는 폐회식에서 시상 예정입니다.  
발표자 전원 참석하여 주시기 부탁드립니다.  
(대리수상을 불가하여 수상자가 불참 시, 차 순위자에게 시상합니다.)

**한국반추위미생물연구회 창립 30주년 기념 심포지엄**  
**(삼다홀, 3층)**

2026년 7월 10일(금) 14:00~17:10

14:00~14:20	등록 (Registration)	
14:20~14:30	개회 / 회장 인사(Welcome Address by the President)	
14:30~15:20	Prof. Isaac Cann (University of Illinois Urbana-Champaign, USA)	Plant Cell Wall Degradation Strategies of Major Rumen Bacteria
15:30~16:20	Prof. Satoshi Koike (Hokkaido University, Japan)	From Early Feeding to Methane Control: Rumen Microbiota's Role in Ruminant Health and Productivity
16:20~17:10	Prof. Jakyem Seo (Pusan National University, Korea)	Hanwoo (beef) industry in South Korea: Challenges and Solutions

**한국반추위미생물연구회 창립 30주년 기념식**  
**(삼다홀, 3층)**

2026년 7월 10일(금) 17:30~20:00

17:30~17:50	개회사 / 축사(Anniversary Ceremony)	
17:50~18:20	Prof. Myung-gi Baik (Former President, KSRFS)	한국반추위미생물연구회 창립 30주년: 성과와 과제 Celebrating 30 Years of KSRFS: Achievements and Challenges
18:20~20:00	Banquet	

# Plenary Lecture

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# Prospects and Development Plans of European Animal Science

Prof. Andrea Rosati  
(EAAP)

## Curriculum Vitae

Dr. Andrea Rosati is the Secretary General of the European Federation of Animal Science (EAAP) and of the World Association for Animal Production (WAAP). He is an accomplished figure in livestock science, combining academic achievement with extensive international management experience. After studying Animal Science in Italy, he earned MSc and PhD in Animal Science in the United States. He spent years in national and international roles managing animal performance recording, genetic evaluations, and global regulatory standards. As a professor, he taught statistics in veterinary faculties at Italian universities and co-managed multiple EU-funded research projects. He co-founded four scientific journals, authored three books and numerous articles, and organizes conferences, webinars, and workshops worldwide. He has managed since more than 20 years EAAP and WAAP. He was honoured with, among the others, the Knight of the French Order of Agricultural Merit and the International Award of American Society of Animal Science. Widely respected, he frequently advises on agriculture, livestock innovation, and global food security.



# Prospects and Development Plans of European Animal Science

European animal science stands at a critical juncture, shaped by converging pressures that simultaneously challenge traditional practices and open new research frontiers. Climate change, resource scarcity, evolving consumer expectations, regulatory frameworks, and the acceleration of digital technologies are redefining the boundaries and priorities of the discipline across the continent. This contribution outlines the current state of European animal science and identifies the strategic directions that will guide its development in the coming decade. Key areas of transformation include the adoption of precision livestock farming (PLF) tools like sensors, artificial intelligence, and data analytics, that are enabling real-time monitoring of animal health, welfare, and productivity. Alongside technological innovation, significant efforts are being directed toward reducing the environmental footprint of livestock production, with particular focus on enteric methane mitigation, circular feed systems, and land use efficiency.



The integration of animal science within broader One Health frameworks represents another important path, reflecting growing awareness of the interdependencies among animal, human, and ecosystem health. In parallel, the sector is confronting structural challenges: workforce renewal, the translation of scientific knowledge into scalable farm-level practices, and the need to maintain competitiveness within an increasingly regulated and market-sensitive environment. European scientific associations, research networks, and industry stakeholders play a central role in coordinating these transitions, fostering cross-disciplinary collaboration and ensuring that innovation remains grounded in robust evidence. The development of structured dialogue between academia and the productive sector is identified as a priority to bridge persistent gaps between research outputs and practical implementation. This contribution argues that the future of European animal science depends on its capacity to embrace complexity, foster interdisciplinary thinking, and position itself as a driver of sustainable food system transformation.



# History of the KSAST and Future Development Directions of the Korean Livestock Industry

김 유 용

Kim, Yoo Yong

(서울대학교)

(Seoul National University)

## Curriculum Vitae

- ▶ 2001~현재 서울대학교 식품동물생명공학부 교수
- ▶ 2024~현재 축산정책포럼 회장
- ▶ 2025~현재 농협중앙회 목우촌 사외이사
- ▶ 2022~현재 (주)사조동아원 사외이사
- ▶ 2014~현재 양돈수급조절협의회 위원장
- ▶ 2012~현재 부경양돈농협 기술고문관
- ▶ 2022 (사)한국축산학회 회장, AAAP 회장
- ▶ 2006~2012 (주)팜스코 사외이사, 도드람양돈농협 사외이사
- ▶ 1994~1999 미국 오하이오주립대학교 축산학과 박사
- ▶ 1983~1990 서울대학교 축산학과 학사, 석사



# History of the KSAST and Future Development Directions of the Korean Livestock Industry

July 8<sup>th</sup> 2026

The Korean Society of Animal Science  
and Technology (KSAST)

Yoo Yong Kim

## Contents

### 1. History of the Korean Society of Animal Science

- Korean Society of Animal Science (1956~1999)
- Korean Society of Animal Science & Tech. (2000~2016)
- Korean Society of Animal Science (2017 ~ Present)

### 2. Development of the English-Language Journal

- 1) Journal of Animal Science and Technology (JAST, 2014 ~ Present)
  - Official Journal of KSAST
- 2) Animal Bioscience (2021.1~ present)
  - Asian-Australasian J. of Ani. Sci. (AJAS, 1988 ~ Dec. 2020)
  - Official Journal of AAAP

### 3. Past Achievements and Future Challenges of the Korean Livestock Industry

## History of KSAS (1956~1999) (KSAS: Korean Society of Animal Science)

Oct. 8<sup>th</sup> 1956. Founded at the meeting room of the Seoul Dairy Cooperative Association in Jeong-dong, Seoul. The society office was established within the Livestock Policy Division of the Ministry of Agriculture (Namdaemun, Seoul)  
"First magazine "Chuksan", "Poultry (L.E. Card)" Translation & Extension

Oct. 1960. The Society Office was relocated to the Dept. Anim. Sci. SNU

May 6 ~ 10<sup>th</sup> 1985. The 3<sup>rd</sup> AAAP Animal Science Congress was held (Walkerhill Hotel, Seoul)

Jan. 1997. The Society Office was moved to Konkuk University

June 28<sup>th</sup> ~ July 4<sup>th</sup> 1998. Hosting the 8<sup>th</sup> WCAP (Seoul National University)

Dec. 1998. The Society Office was moved to KOFST #908

### Dec. 28<sup>th</sup> 1999. Integration of Four Academic Societies

한국축산학회, 한국영양사료학회, 한국동물유전육종학회, 한국낙농학회

- Establishment of the Korean Society of Animal Sciences and Tech. Sciences of Poultry, Reproduction and Grassland & Forage remain independent, and their integration has been deferred.

한국가금학회, 한국번식학회, 축산환경학회, 한국조지학회는 현재도 통합보류 상태임

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## History of KSAST (2000 ~ Present)

Jan. 1<sup>st</sup> 2000: Korean Society of Animal Sciences and Technology  
→ Launch of the KAST Journal (Korean)

Sep. 18<sup>th</sup> ~20<sup>th</sup> 2006: Hosting of the 12<sup>th</sup> AAAP ASC (Bexco, Pusan)  
Co-Hosting of the 50<sup>th</sup> Anniversary of the KSAST

Feb. 2014 : Publication of the "Livestock Terminology Dictionary"

June 23<sup>rd</sup> ~ 24<sup>th</sup> 2016: The 60<sup>th</sup> Anniversary of the KSAST (Seoul National Univ.)

Nov. 2016: The General Assembly approved a resolution to change the Society's name from the "Korean Society of Animal Science & Technology" to the "**Korean Society of Animal Science**"

- The change required final approval after a review of the Society's bylaws by the Government

Jan. 1<sup>st</sup> 2017: Lunch of the Korean Society of Animal Science

### May 25<sup>th</sup> 2017: Relocation to Suite 1618, Suseo Tower, Seoul

- The office was purchased for KRW 210 million using the surplus funds from the 12th AAAP

Aug. 23~26 2022: 19<sup>th</sup> AAAP Animal Science Congress (Jeju, ICC)

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## History of Journal of Anim. Sci. & Tech.

- 1999 – Korean J. of Ani. Sci. was selected as a candidate Journal by Korea Research Foundation (KRF)
- 2006 – 50th Anniversary Meeting of KSAST (Bexco, Busan)
- 2011 – Accredited Journal by KCI
- 2013 – ACOMS Submission System Setup and Deployment
- 2014 – Lunched of the English-language Journal “J. of Ani. Sci. & Tech.” under leadership of Inho Choi to an Open Access Journal  
Established an integrated manuscript and management and publication (DOI, XML, ORKID)
- 2015 – Indexed in PubMed (articles published from 2014 onward)
- 2016 – 60<sup>th</sup> Anniversary Meeting of KSAST (Seoul National Univ., Seoul)
- 2018 – **Under the leadership of Prof. Sejong Oh, application for SCIE indexing submitted in Dec. 2018**  
**Indexed in SCOPUS (approx. KRW 500 Mil. won since 2014)**
- 2019 – Indexed in the SCIE (Science Citation Index Expanded)
- 2026 – 70th Anniversary Meeting of KSAST (ICC, Jeju)

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## Meeting with BMC in 2018

일시	회의 내용	논의 사항
1월 26일	BMC 담당자와의 화상회의	BMC의 APC 비용 저감화 요청
2월 9일	BMC 담당자로 부터 JAST APC 재계약에 대한 이메일을 받음	30편: 학회부담 €930/편 10편: 저자부담 €1,200/편 -40편 발간 기준 €1,065/편 (약 140만원/편)
2월 12일	BMC 담당자에게 답신 메일	학회에서 충분히 시간을 갖고 논의해서 통보해 주겠다는 메일 발송
6월 29일	영문학술지 편집위원회 개최(중앙대)	SCIE 등재 준비를 위한 TFT 구성 (BMC에서 재계약시 재정적 부담 시뮬레이션 논의)
8월 9일	<b>허선 과편협위원장(한림의대) 컨설팅 (BMC와 계속 같이 가는 것이 유리할까?)</b>	<b>결론: 유리한 점이 별로 없음</b>
9월 12일	한국축산학회 4차 이사회	BMC와의 결별 및 신규 출판사 승인 (거목출판사) 도메인 확보 및 BMC 논문 이전 작업 개시
11월 16일	신규 JAST 홈페이지 회원 공지	신규 투고 시스템 및 학술지 홈페이지 Open
11월 18일	BMC 담당자에 이메일 재계약 여부 통보	축산학회 총회에서 BMC 계약 연장을 안하기로 했음을 통보

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## Consulting by Prof. Sun Huh

*Journal of animal science and technology*를 SCOPUS, SCIE 에 등재시키기 위하여 BMC와 계속 같이 하는 것이 유리할까?

허선  
한림의대

한국축산학회 학술지 모임  
2018. 8.9. 오후 4시  
수서타워 1618호

**- Conclusion -**  
**It is not a disadvantage, but there is also no aspect that stands out as an advantage.**

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항목	2018	2019	2020
Public APC (저자가 부담)	10편 €1,200 = 약 158만원	15편 €1,200 = 약 158만원	20편 €1,745 = 약 229만원
	€12,000 = 약 1,580만원	€18,000 = 약 2,844만원	€34,900 = 약 4,582만원
Society Covered Articles	30편	30편	30편
APC for Society covered articles (학회가 부담)	€930 = 약 122만원	€930 = 약 122만원	€1,100 = 약 144만원
	€27,900 = 약 3,663만원	€27,900 = 약 3,663만원	€33,000 = 약 4,333만원
<b>Total Cost</b>	€27,900 = 약 5,243만원	€27,900 = 약 6,507만원	€33,000 = 약 8,915만원

2018년 평균 송금보내실 때 환율; 1,313원/€

- ✓ 학회가 부담하는 가격은 할인되어 €930 이지만 이것도 저자가 내야 함.
- ✓ 2016년 부터 게재료(50만원/편)를 받고 나머지를 학회가 부담하였음.
- ✓ 재계약시, 학회가 2018년 3,243만원, 2019년 4,257만원, 2020년 6,415만원 이상을 현금으로 송금해야 함.
- ✓ BMC와의 계약이 필요하는가? 에 대한 논의를 시작함.

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## Notice of Non-Renewal of the Publishing Agreement with BMC

Re: Message from Sejong (Journal of Animal Science and Technology)

**Dylan Parker** <dylan.parker@biomedcentral.com>  
 받는 사람 Sejong Oh  
 참조 Sunny Kim; Vicky Brewis

↶ 회신   ↶ 전체 회신   → 전달   ...

2018-11-18 (일) 오후 8:14

Dear Dylen,

Sorry for late reply. There was a director meeting of the Korean Society of Animal Science & Technology on Oct 18th, a council on Oct 30<sup>th</sup>, and 11th this month the General meeting of society members was held. I expressed at the board meeting that we extend our contract with BMC, and we should publish the 48 articles per year at least. I stated again that if we are to extend the contract with BMC for 3 years, the overhead cost could be around US\$100,000.

Not only is BMC an exemplary publisher, but also enhanced the quality of our journals. I also expressed that another great benefit with BMC is that there was no need for unnecessary associates being added to the publication process, which would keep our costs low. If we are not extending with BMC, we would have to bring on board at least 1 more associate.

However, the some of directors disagreed and did not accept my proposition. Even at the council meeting, they said the same. I felt rather bitter about their decisions, so I did not attend the general meeting, but during the final members assembly they decided not to extend the contract with BMC.

I asked to the president for resignation of my position as Chief-editor by the phone, and currently waiting for their confirmation. How can one not see the numerous benefits that BMC provides while reducing our operating costs to the minimum? This was surely a disappointing moment for me.

Anyway, I want to thank you for all the help and support. It has been a tremendous experience for me and I hope our paths will cross in the near future.

Best wishes,

Sejong

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## 2026 JAST Editorial Board Members

직책	성명	영문명	영문소속	심사전문분야
Editor-in-Chief	김영훈	Younghoon Kim	Seoul National University	Animal microbiology and biotechnology, Animal product
Associate Editors-in-Chief	송민호	Minho Song	Chungnam National University	Non-ruminant nutrition
	김민석	Minseok Kim	Chonnam National University	Ruminant nutrition
Editors	공창수	Changsu Kong	Kyungpook National University	Non-ruminant nutrition
	김현범	Hyeun Bum Kim	Dankook University	Animal microbiology and biotechnology, Animal disease
	김준모	Jun-Mo Kim	Chung-Ang University	Animal genetics/breeding, Animal microbiology and biotechnology
	김영후	Myunghoo Kim	Seoul National University	Animal microbiology and biotechnology, Ruminant nutrition
	한건준	Kun-Jun Han	Louisiana State University, USA	Forage and Feed technology
	박규현	Kyu-Hyun Park	Kangwon National University	Animal environments, Animal welfare
	박희복	Hee-Bok Park	Kongju National University	Animal genetics/breeding
	허선진	Sun Jin Hur	Chung-Ang University	Animal product, Meat Science
	박탄술	Tansol Park	Chung-Ang University	Ruminant nutrition, Animal microbiology and biotechnology
	김성학	Sung-Hak Kim	Chonnam National University	Animal Microbiology and Biotechnology, Cell biology
	최정석	Jungseok Choi	Chungbuk National University	Animal product, Meat Science
	서자경	Jakyeom Seo	Busan National University	Ruminant nutrition
	김진수	Jin-Soo Kim	Kangwon National University	Non-ruminant nutrition
	이승환	Seung Hwan Lee	Chungnam National University	Animal genetics/breeding
	오성진	Seongjin Oh	Hokkaido University, Japan	Ruminant nutrition
	허정민	Jung Min Heo	Chungnam National University	Non-ruminant nutrition
유영록	Kyung-Rok Yu	Seoul National University	Animal microbiology and biotechnology, Stem cell biology	
송수연	Sooveon Song	Jeonbuk National University	Animal product, Dairy Science, Animal microbiology and biotechnology	
Junior Editors	김동혁	Jong Hyuk Kim	Chungbuk National University	Non-ruminant nutrition
	박상우	Sangwoo Park	Gyeongsang National University	Non-ruminant nutrition
	이준희	Joonhee Lee	Kyungpook National University	Animal environments, Animal welfare
Ethics Editor	함지연	Jiveon Ham	Chunonam National University	Animal reproduction, Animal microbiology and biotechnology
	조철준	Cheoron Jo	Seoul National University	Animal product, Cultured meat science

**A total of 28 editors are currently serving JAST.  
 Beginning in 2026, 4 Junior Editors are appointed to increase the participation of early-career researchers in the editorial process**

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## JAST Publication Statistics

Items	2023 Vol. 65	2024 Vol. 66	2025 Vol. 67	2026 Vol. 68	Total
1	18	16	18	21	73
2	15	16	17	18	66
3	16	16	16	21	69
4	16	16	16	-	48
5	16	16	16	-	48
6	16	18	17	-	51
<b>총계</b>	<b>97</b>	<b>98</b>	<b>100</b>	<b>60</b>	<b>355</b>
Number of Submission	<b>291</b>	<b>343</b>	<b>372</b>	(150; As of May)	

Manuscript submissions to JAST have consistently increased year by year

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## Performance Analysis of JAST in 2026

2024 JOURNAL IMPACT FACTOR

3.2

(Q1)

[View calculation](#)

### Calculation

Journal Impact Factor™ is calculated using the following metrics:

$$\frac{\text{Citations in 2024 to items published in 2022 (356) + 2023 (258)}}{\text{Number of citable items in 2022 (94) + 2023 (96)}} = \frac{614}{190} = 3.2$$

JOURNAL IMPACT FACTOR WITHOUT SELF CITATIONS

2.9

[View calculation](#)

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## Performance Analysis of JAST in 2026

### Journal Impact Factor contributing items

Citable items (190)		Citing Sources (203)
TITLE	CITATION COUNT	
Gut microbiome-produced metabolites in pigs: a review on their biological functions and the influence of probiotics	28	
Perspectives and advances in probiotics and the gut microbiome in animals	22	
Effects of different <i>Bacillus licheniformis</i> and <i>Bacillus subtilis</i> ratios on nutrient digestibility, fecal microflora, and gas emissions of...	13	
How to develop strategies to use insects as animal feed: digestibility, functionality, safety, and regulation	13	
Recent strategies for improving the quality of meat products	13	
Enhanced $\gamma$ -aminobutyric acid and sialic acid in fermented deer antler velvet and immune promoting effects	12	
Heat stress and stallion fertility	12	
Development of strategies to manufacture low-salt meat products-a review	11	
The roles of growth factors and hormones in the regulation of muscle satellite cells for cultured meat production	11	
Comparative analysis of the pig gut microbiome associated with the pig growth performance	10	

Highly cited publications are concentrated in emerging research areas that have become key issues in the livestock industry, such as microbiomes, insect-based feed, livestock environmental sustainability, companion animals, and cultured meat etc.

**By the way, what are its practical applications in livestock production ?**

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## Performance Analysis of JAST in 2026

CATEGORY  
AGRICULTURE, DAIRY & ANIMAL SCIENCE

11/86

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2024	11/86	Q1 *	87.8
2023	10/80	Q1	88.1

Rank by JIF before 2023 for AGRICULTURE, DAIRY & ANIMAL SCIENCE

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2022	18/62	Q2	71.8
2021	35/62	Q3	44.35
2020	20/63	Q2	69.05
2019	20/63	Q2	69.05

CATEGORY  
VETERINARY SCIENCES

12/170

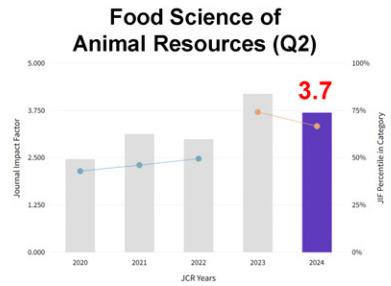
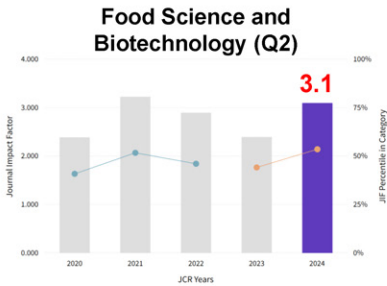
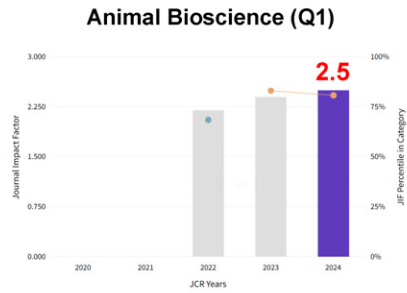
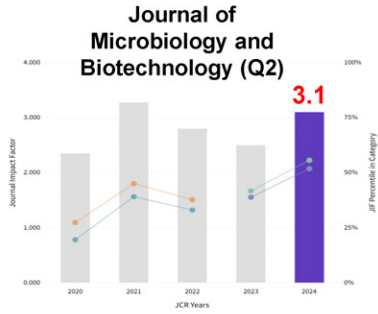
JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2024	12/170	Q1 *	93.2
2023	16/167	Q1	90.7

Rank by JIF before 2023 for VETERINARY SCIENCES

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2022	35/144	Q1	76.0
2021	58/145	Q2	60.34
2020	39/146	Q2	73.63
2019	38/141	Q2	73.40

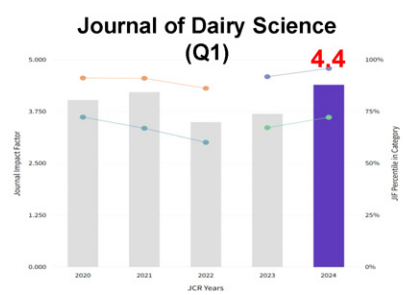
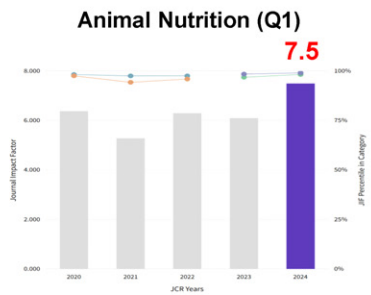
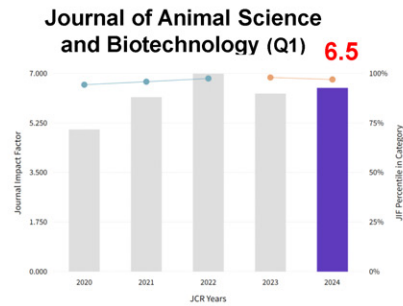
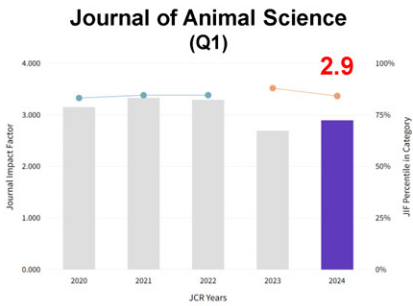
14

## Performance Analysis of JAST in 2026



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## Performance Analysis of JAST in 2026



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## AAAP

(Asian-Australasian Association of Animal Production Societies)

- **Founded in 1980 with 8 member countries**, currently 19 member countries: **Australia**, Bangladesh, China, India, **Indonesia**, Iran, **Japan**, **Korea**, **Malaysia**, Mongolia, Nepal, **New Zealand**, Pakistan, Papua New Guinea, **Philippines**, Sri Lanka, Taiwan, **Thailand**, Vietnam
- **Activities : Biennial AAAP ASC, Official Journal (Anim. Biosci.) Publication**
- Permanent Secretariat of AAAP: Suite 1618 Suseo Tower, Seoul Korea
- Secretary General of AAAP Secretariat: All managerial works for AAAP with 6 years term by approval by the Council
- Secretary General of AAAP Secretariat
  - 2000 ~ 2010 Prof. J. K. Ha
  - 2011 ~ 2024 Prof. S. J. Ohh
  - 2025 ~ Present Prof. Y. Y. Kim
- **A resolution was adopted that the President of the AAAP Congress and the President of KSAST shall be the same person whenever the AAAP Congress is held in Korea**

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## AAAP ASC in Korea

### The 3<sup>rd</sup> AAAP ASC

Date: May 6~10 1985, Place: Walkerhill Hotel, Seoul  
President: In K. Han, Chairman of OC: D. A. Kim,  
Secretary General of OC: H. W. Kim

### The 12<sup>th</sup> AAAP ASC

Date: Sep. 18~22 2012, Place: Bexco, Busan  
President: In K. Paik, Chairman of OC: S. J. Ohh  
Secretary General of OC: Y. Y. Kim

- Donated an AAAP surplus of KRW 220M to KSAST
- Purchased the Society Office at Suseo Tower in 2017

### The 19<sup>th</sup> AAAP ASC

Date: Aug. 23~26 2022. Place: ICC, Jeju  
President: Yoo Yong Kim, Chairman of OC: Sejong Oh,  
Secretary General of OC: Jun Heon Lee

- Funds were deposited into the Society's Savings Account



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## The 21<sup>st</sup> AAAP ASC

Date: Oct. 28~31 2026. [www.aap2026.org](http://www.aap2026.org)

Place: Hanoi, National Convention Center

President: Nguyen Zuan Duong, Vice President: Do Duc Luc

Early-bird registration deadline 31<sup>st</sup> July 2026

Normal registration opens 1<sup>st</sup> August 2026

Presenter registration deadline 31<sup>st</sup> August 2026

**AAAP prize awardee was confirmed : Sang Jip Ohh**

## The 22<sup>nd</sup> AAAP ASC

Date: Sep. 2028.

Place: Pattaya, Thailand

President: Suthep V., Vice President: Chaiyapoom Bunchasak

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## History of AJAS, Animal Bioscience

### 1987 Established and approved at the 4<sup>th</sup> AAAP ASC

1988 Lunched with the Journal of Korean Society of Animal Nutrition and Feed Science

Office location: 1988 ~ Feb. 2000 Seoul National Univ. Suwon Campus

Mar. 2000 ~ Mar. 2004 Gwacheon Officetel, Kyeonggido

April 2004 ~ Present Suite 708 Sammo Sporex, Sillimdong,

Purchase Office by bank loan (KRW 100 Mil. J. K. Ha and Y. Y. Kim)

2000. 2. 21. Declare "Official English Journal of KSAST"

### Name of Journal

1988 ~ Dec. 2020 Asian-Australasian Journal of Animal Sciences

Jan. 2021~ Present **Animal Bioscience**

### Editor-in-chief:

In K. Han (Mar.1988 ~ June 1994/ Aug.1998 ~ Oct. 2001)

Dong Am Kim (Sep. 994 ~ June 1998)

Jong K. Ha (Nov. 2001 ~ Dec. 2025)

Cheol H. Yun (Jan. 2026 ~ Present)

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## The Evolution of South Korea's External Policies on the Livestock Industry

**GATT (1967~1980):** Strong protection policies for key agricultural products such as rice and beef

- South Korea benefited from favorable conditions by being recognized as a developing country

**UR (1986~1994):** Beginning of agricultural tariffication in international trade

- The elimination of non-tariff barriers began
- Pressure increased to open the domestic agricultural market
- The government started reducing agricultural subsidies
- Most agricultural markets were opened, but rice secured a temporary exemption from tariffication

**WTO (1995):** Opening of the domestic agricultural market

- The domestic beef market was fully liberalized, and tariffs on agricultural products were reduced
- Government support shifted from price-support policies for agricultural products to direct payments and measures aimed at improving agricultural competitiveness

**Rice Market Liberalization Debate (1995–2015):** Temporary exemption from rice tariffication until 2013

- Beginning in 2015, rice imports became subject to a 513% tariff

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## The Evolution of Korea's External Policies on the Livestock Industry

**FTA Era (2004~Present) :** The Beginning of Global Competition

**2004. Korea-Chile FTA** – Competition in grapes and other fruit markets

**2007. Korea-ASEAN FTA** – Agreement signed with the 10 ASEAN member countries, covered agricultural products, services sectors

**2011. Korea-EU FTA** – Competition intensified across the livestock sector

- Imports of cheese, pork, and wine increased, while exports of automobiles, electronics, and ships grew
- Domestic agriculture shifted from a protection-oriented system to a competitiveness-oriented system

**2012. Korea-U.S. FTA** – Competition in livestock products intensified in the domestic market

**2015. FTAs with China, New Zealand, Vietnam, and Canada**

- Broad competition began across agricultural and livestock products

**2022. Regional Comprehensive Economic Partnership (RCEP)**

- A trade agreement involving 15 countries in the Asia-Pacific region (30% of the world's population and GDP)

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## The History of the Korean Livestock Industry (1950 ~ '59)

**Because of Korean War, Korea's livestock industry was severely damaged**

**Hanwoo – During the colonial period, only brown Hanwoo remained**

- White, Black, Tiger and White Hanwoo began to be restored from 1990s
- Before 1950, cattle were mainly used for draft and farming purpose
- Hanwoo markets were formed nationwide with traditional 5-d markets

**Dairy Cattle – Before the Korean War: about 1,000 head**

- After the war, decreased to 289 head (1954), increased again to 766 head by 1959

**Swine – small-scale backyard farms with 1–2 pigs per household**

- Around 1950, there were about 1 million pigs
- Feed consisted largely of food scraps and agricultural by-products

**Laying Hen – Eggs were regarded as a very valuable source of nutrition**

- Eggs were often sold in small bundles of ten

**Broiler – There was no specialized broiler industry**

- Chickens were considered special foods reserved for special occasions

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## Development of the Korean Hanwoo and Dairy Industries (1956 ~ '80)

**Hanwoo – Widespread confiscation and illegal slaughter of cattle**

- Hanwoo breeding and genetic improvement programs were initiated
- The breeding objective shifted from draft cattle to beef cattle (1950s)
- Livestock AI center was established by Nonghyup (1960s)
- The Livestock Industry Act was enacted, introducing cattle markets and auction systems
- An artificial milk replacer for Hanwoo calves was developed

**Dairy Cattle Industry**

- After the Korean War, the dairy cattle population declined to 289 head
- In 1961, dairy cattle were imported from New Zealand
- In 1963, 271 dairy cattle were imported from the US and Canada.
- **In 1967, additional dairy cattle were imported from Japan using funds from the Korea–Japan Claims Settlement Agreement.**
- Professor Yong-Bin Lee of Seoul National University introduced AI technology from Japan, enabling the rapid expansion of superior cattle
- In 1979, the Dairy Herd Improvement (DHI) Program was launched

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## Development of the Korean Hanwoo and Dairy Industries (1981 ~ '00)

**Hanwoo** – Population was increased 1.94 Mil. head in 1983

- In 1983, the Hanwoo Improvement Center was established
- In 1987, proven breeding bulls were selected, and their semen was distributed nationwide
- In 1992, the Livestock Carcass Grading System was introduced
- From 1995 to 1998, a nationwide cattle identification and computerized management system was implemented
- In 1999, the National Hanwoo Association was established
- Genetic improvement programs were expanded and implemented at the individual farm level.

**Dairy Cattle** – In 1981, high-quality dairy cattle semen was imported from the US

- By 1985, a total of 113,059 dairy cattle had been imported from overseas.
- Population increased from 1,956 head in 1962 to 544,000 head in 2000, representing a 278-fold increase
- In 1994, the first four proven dairy sires were officially selected
- UR settlement, imports of all dairy products, except skim milk powder
- In 1997, the Dairy Promotion Act was revised, and the School Milk Program became an established national program
- In 1999 livestock wastewater were strengthened to protect the Han River

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## Development of the Korean Hanwoo and Dairy Industries (2001 ~ Present)

**Hanwoo** – A system for high-quality premium Hanwoo beef has been established.

- Continuous efforts for genetic improvement, branding programs
- Following the COVID-19 pandemic, beef consumption increased  
→ oversupply → decline in Hanwoo prices
- Check-off Program launched (Nov. 1<sup>st</sup> 2008)
- Although substantial research has been conducted in the field of BT  
many of these technologies have not yet been fully adopted at the farm level  
ex) ET, Twin production, Cloning, Transgenic cattle, Fluorescent Hanwoo

**Dairy Cattle** – dairy cow has decreased, while milk production per cow has increased

- Since 2002, free school milk programs have been provided
- The Dairy Check-off Program was launched on February 20, 2013
- In 2014, domestic milk production reached a record high of 2.2 million tons.
- Since 2017, dairy product imports have exceeded domestic milk production
- Due to Korea's declining birth rate, consumption of fluid milk has decreased, while cheese consumption has increased.
- Beginning in 2026, tariff-free imports of dairy products from the US and EU

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## Development of the Korean Swine Industry (1956 ~ '80)

### Swine – In 1960s, pig inventory 1 mil. pigs, backyard farming

- Samsung established the Swine Production Division at Yongin
  - May 1973: The Yongin Natural Farm pig farm was opened, marking the beginning of large-scale commercial pig farming in Korea
  - The operation expanded to a herd size of 60,000 pigs, becoming the largest pig farm in Asia at the time.
  - Introduced 3-way crossbreeding, artificial insemination (AI), computerized herd management, and vertically integrated production systems.
  - In 1991, Samsung Group completely withdrew from the swine industry
- **In 1970, pig inventory 1.2 mil. pigs, swine farms 1 mil.**
- In 1973, Cheil Breeding Co., was established
  - Wooden and steel trusses with slate roofing began to be used in pig housing
  - Automatic feeding systems were introduced
  - controlled ventilation gradually replaced natural ventilation in swine buildings
- In 1978, Established Korea Pork Producers Association
- In 1980, pig inventory 2.84 mil., swine farms 0.65 mil.

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## Development of the Korean Swine Industry (1981 ~ '00)

### Swine: Farm consolidation and specialization

- The beginning of productivity improvement efforts in swine production
- **The establishment of domestic swine breeding companies (Darby)**
  - The beginning of large-scale imports of superior breeding stock from abroad
  - Adoption of the Landrace × Yorkshire × Duroc 3-way crossbreeding system
- **Emergence of large-scale pig farms raising more than 1,000 pigs**
- **Expansion of commercial feed production led by feed companies**
- **Increasing efforts to improve productivity and production efficiency**
  - Widespread adoption of artificial insemination (AI)
  - Modernization of swine housing facilities
  - Dissemination of advanced pig management technologies
- **Growing popularity and widespread consumption of pork**
  - Pork emerged as the dominant meat in domestic meat consumption
- 1993–1999: Establishment of the Korea Meat Export Association
  - beginning of pork exports to Japan and terminated because of FMD (2000)

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## Development of the Korean Swine Industry (2001 ~ Present)

### Swine – Disease Outbreaks and Strengthening of Biosecurity Measures

- 2002: Outbreak of Foot-and-Mouth Disease (FMD) → suspension of pork exports
- 2010–2011: FMD outbreak resulted in the culling of approximately 3.3 mil. Livestock, including 3.14 mil. of pigs
- Establishment of dedicated government agencies, including the Bureau of Animal Health Policy and the Bureau of Animal Welfare Policy

### ➤ Vertical Integration of the Swine Industry

- Increasing integration of swine-related companies across the production chain.
- Development of vertical integration systems led primarily by feed companies and breeding stock companies

### ➤ Adoption of ICT and smart farming technologies

- Implementation of automated feeding, liquid feeding, environmental control, AI-based technologies, and remote farm management
- Livestock manure management became a major challenge for the swine industry
- A nationwide ban on ocean dumping of livestock manure took effect in 2012

### ➤ ESG, Animal Welfare, Farm Odor Problems

- Check-off Program launched (July 1<sup>st</sup> 2004)
- Antibiotics issue (Ban on AGP from July 1<sup>st</sup> 2011)
- Carbon Neutrality Policy

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## Development of the Korean Poultry Industries (1956 ~ '00)

### Poultry – 1958: Establishment of the Korean Poultry Research Society

- Imported chicken breeds began to be introduced from overseas in the mid-1950s.
- The 1960s marked the early stage of part-time and specialized commercial poultry farming.
- 1962: Establishment of the Korea Poultry Association; 1969: Launch of the monthly poultry magazine “Wolgan Yanggye (Monthly Poultry Farming)”.
- Consumption of chicken meat and eggs increased significantly during the 1970s

### ➤ In the early 1970s, poultry production shifted from floor-rearing systems to battery cage improving production efficiency and flock management

### Broiler - Introduction of imported broiler breeds in the 1960s

- Importation of broiler breeder stocks beginning in 1965
- Commercial production and marketing of specialized broiler feeds
- Establishment of the first dedicated broiler slaughter and processing plant in 1968

### ➤ 1970s: A Period of Rapid Growth for the Korean Poultry Industry

- Introduction of pure-line stocks provided the foundation for poultry breeding
- Establishment of feeding programs for layers and broilers
- Productivity improvements through protein nutrition research and the use of synthetic AAs

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## Development of the Korean Poultry Industries (1980 ~ '00)

### **Poultry – Entered an era of full-time commercial production**

- Increasing specialization within the industry, including hatcheries, brooding operations, and egg grading and packing centers (EPCs).
- Introduction and marketing of specialty eggs.
- Development of the egg processing industry (including liquid, dried, value-added egg)
- The layer industry experienced a prolonged boom during the mid-1970s.
- the number of large-scale poultry farms and various diseases are increased

### ➤ **Chicken meat imports began in 1997**

- The chicken meat self-sufficiency rate declined to the 80% in 2008
- Expansion of supermarkets and hypermarkets enhanced poultry product distribution
- Shift from whole-bird sales to cut-up parts and processed poultry products

### ➤ **Emergence of integrated broiler production companies**

- Harim established its poultry processing operation in 1991
- Productivity improvements through protein nutrition research and synthetic AAs
- Diversification of poultry manure treatment methods (drying, composting, pelletizing)

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## Development of the Korean Poultry Industries (2001 ~ Present)

### **Poultry – Restoration and genetic improvement of native chicken**

- Development of purpose-specific native chicken strains (e.g., Woorimatdak)
- Declining number of farms but increasing poultry population
- Implementation of the Egg Production Environment Labeling System on Aug. 2018

### ➤ **Check-off Program Launched**

- July 1<sup>st</sup> 2008 Broiler Check-off Program Launched
- Aug. 1<sup>st</sup> 2009 Egg Check-off Program Launched

### ➤ **Repeated AI outbreaks leading to large-scale culling of poultry**

- 2012–2014: Approximately 20 million birds culled due to AI
- 2016–2017: Approximately 38 million birds culled during the HPAI outbreak
- Since 2017, outdoor ranging of poultry has been prohibited from Oct. to Feb.
- Since 2017, winter restrictions on duck placement have been enforced to prevent AI outbreaks

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## Development of the Korean Feed Industry (1956 ~ '80)

### **In 1955, Hanwoo .87mil. Swine 1.26 mil. Poultry 892mil.**

- 1959: Seoul Livestock Cooperative signed a contract to supply 300,000 eggs to the U.S. military
  - Imports of feed sorghum and Thai rice bran began to support feed manufacturing
  - In 1964, Domestic concentrate feed production surpassed 1 mil. tons
- **Launch of the Five-Year Economic Development Plans**
  - July 1961: Establishment of the Korea Feed Industry Association (KFIA)
  - 1962: Introduction of tariff exemptions for imported feed grains
  - 1963: Enactment of the Feed Control Act
  - 1964: Number of licensed feed mills increased to 46
- **The 1970s: A Period of Rapid Growth for the Korean Feed Industry**
  - 1977, Korea's per capita GNP exceeded US\$1,000
    - ➔ Feed: Over mil. tons for poultry feed (1977), swine feed (1979)
  - Government-controlled feed prices were liberalized in 198
  - Feed Price Stabilization Fund introduced in 1975
  - Rapid growth of livestock populations, particularly dairy cattle
  - 1979: 78 feed mills with a combined capacity of 8,780 tons/day

33

## Development of the Korean Feed Industry (1980 ~ '00)

### **Growing demand for livestock products and feed price deregulation**

- 1981: Establishment of the Nonghyup
- 1983: Cattle price collapse caused major damage to the Hanwoo industry
- 1984: Korea Feed Association headquarters relocated to Seocho-dong, Seoul
- **Seminars on feed tech. and animal nutrition began in the 1980s**
  - Participation by the Korea Feed Association, U.S. Grains Council, and Canadian Embassy
  - Seminars held 2-4 times annually with contributions from academics and researchers
  - Introduction of short courses in animal nutrition and feed science for industry personnel
  - Expansion of international cooperation and tech. exchange in feed production
- **1989: Compound feed production reached 10 million tons**
  - UR Agreement, opening of the beef market; full liberalization in 2001
  - Import liberalization of pork and poultry products began in 1997
  - Expansion of feed additives and feed supplements since the 1990s
- **The 1990s marked a period of stagnation in compound feed production**
  - Private feed companies dominated the poultry, swine, and dairy feed sectors, while Nonghyup feed focused on cattle feed
  - Beginning of overseas expansion by major feed companies

34

## Development of the Korean Feed Industry (2001 ~ Present)

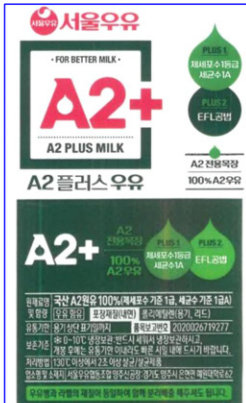
- **Livestock Becomes the Leading Sector of Korean Agriculture**
  - Livestock's share of agricultural output increased from 14.9% in 1970 to 41.9% in 2010
  - The livestock sector accounted for about 60% of total agricultural losses associated with FTA implementation
- **Large-scale livestock disease outbreaks**
  - Introduction of various diseases through international exchange and importation of foreign breeds
  - FMD outbreaks began in 2000
  - 2007 BSE crisis significantly affected the Hanwoo industry
  - 2010–2011 FMD outbreak led to the culling of approximately 3.5 million animals
  - Recurring AI outbreaks and ASF outbreaks since 2019
- **Introduction of the HACCP system**
  - Initially applied mainly to processing facilities in other countries
  - Expanded to the farm level in Korea beginning in 2006
- **Global expansion of the Korean feed and livestock industry**
  - Expansion of the feed and swine industries into Southeast Asia
  - Further expansion into the United States, the EU, South America, and India

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## The Role of Academic Societies in the Development of the Korean Livestock Industry

- **The Importance of Leadership in Academic Societies**
  - Promote transparent and efficient governance
  - Make every effort to secure financial resources through fundraising
  - Strengthen academic activities and industry collaboration
- **Views on Future Research Directions**
  - Promote balanced development across research disciplines
  - Support research that advances the Korean livestock industry and related sectors
    - ➔ Emphasize practical applications and technology
  - Identify and foster research areas needed by the livestock industry
- **Continued support and investment for the development of the journals**
  - Sustained investment in the SCI-indexed English journal to enhance its global competitiveness
  - Establishment of a committee or center to document the history of the Society and the livestock sector (70th Anniversary Initiative)
- **Strengthen international collaboration with researchers**
  - Further revitalize AAAP and reinforce Korea's role as a leading country
  - Promote academic exchange and technical assistance for developing countries


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**서울우유**  
A2+  
A2 플러스 우유

## Is the Dairy Industry a Sunset Industry ?

➤ **Coca-Cola launched a premium milk brand, Fairlife (formerly marketed as Select Milk), and its fluid milk sales increased by 25.3% in 2025, reaching about KRW 1.4 trillion (US\$1 billion).**



**Maell**  
소화가 잘되는 우유  
UF  
공법

- **Approximately 70% of Holstein dairy cows in Korea produce A1 β-casein**  
- In A1 β-casein, the 67th amino acid is histidine, while in A2 β-casein it is proline
- Originally, all cattle produced A2 β-casein. A mutation that occurred thousands of years ago gave rise to cattle producing A1 β-casein
- **Studies have suggested that symptoms of lactose intolerance may improve by approximately 20–50% when consuming A2 milk**

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**My sincere appreciation goes to all those who helped prepare this material**

- **JAST, Journal:** Prof. Sejong Oh (Chonnam National Univ.)  
Prof. Younghoon Kim (Seoul National Univ.)
- **Hanwoo:** Executive Director, Jong Soo Kim (Nonghyup)
- **Swine:** CEO, Seong Kyu Yun (Darby Genetics)
- **Poultry:** Senior Managing Director, Dong Jin Kim (Korea Poultry Association)

Senior Managing Director, Ick Sub Kwon  
(Kyesung Laying Hen, Ltd)

- **Feed:** Korea Feed Association (KFA)







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**Thank you very much for your kind attention~~**



# Animal Genetics, Past, Present and Future

이 준 현

Lee, Jun-heon

(충남대학교)

(Chungnam National University)

## Curriculum Vitae

- ▶ 2002~현재 충남대학교 농업생명과학대학 동물자원생명과학과 교수
- ▶ 2024~현재 첨단분야혁신융합대학(COSS) 그린바이오 총괄사업단장
- ▶ 2026~현재 충남대학교 연구처 처장, 산학협력단 단장, RISE 사업단 단장, 미래창업원 원장
- ▶ 2023~2025 충남대학교 농업생명과학대학 학장
- ▶ 2025.01~12 한국축산학회 회장
- ▶ 2023~2025 한국동물유전육종학회 회장
- ▶ 2020~2025 세계동물유전학회(ISAG2025) 조직위원장
- ▶ 2008~2009 미국 미시간대학교 방문연구교수
- ▶ 2005.06~07 일본 고베대학교 방문연구교수
- ▶ 2001~2002 미국 일리노이대학교 박사후연구원
- ▶ 1997~2001 호주 시드니대학교 농과대학 축산학과 동물분자유전학 농학박사
- ▶ 1993~1995 충남대학교 대학원 축산학과 가축번식육종학 농학석사
- ▶ 1987~1991 충남대학교 농과대학 축산학과 농학사



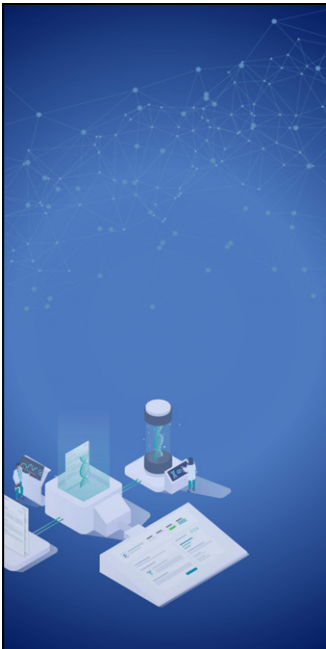
# 가축유전학의 과거, 현재, 그리고 미래

(Animal Genetics: Past, Present, and the Future)

2026년도 한국축산학회 국제연합심포지엄 및 학술발표회  
2026. 07. 09.

이준현

충남대학교 농업생명과학대학 동물자원생명과학과 교수  
충남대학교 연구처장 / 산학협력단장



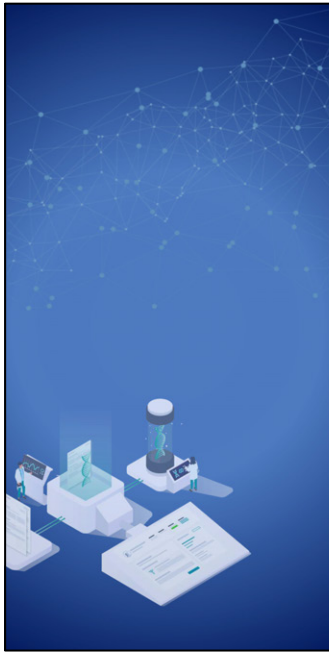
Chapter 01 재래가축의 가치와 가축유전학의 출발

Chapter 02 마커와 유전체로 읽는 재래가축의 유전적 가치

Chapter 03 예측과 설계로 확장되는 가축유전학

Chapter 04 유전정보가 이끄는 지속가능한 축산





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Chapter 01 재래가축의 가치와 가축유전학의 출발



● 재래가축의 중요성

보존 및 활용 가치가 높은 유전자원



한국 토종닭



한국 재래돼지



한우



환경 적응성



질병 저항성



유전 다양성



문화·농업 유산



❶ 한국의 토종닭 집단

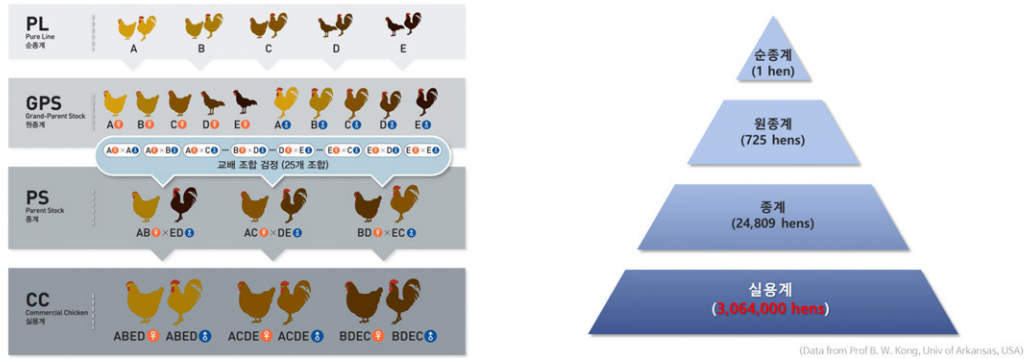


❷ 상업계통 편중에 따른 유전적 다양성 감소 우려

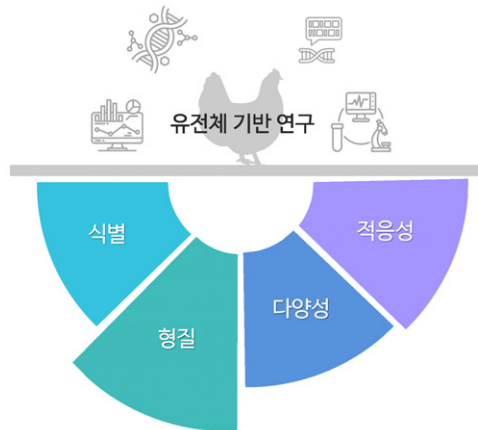


유전자원 보존 및 개량의 필요성

- 한 마리의 순종계(PL) 종자가 약 3,064,000마리의 실용계(CC) 생산



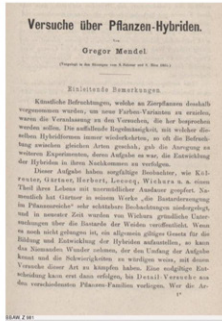
보존과 개량을 위한 유전정보의 역할



멘델 유전학 (Mendelian Genetics)



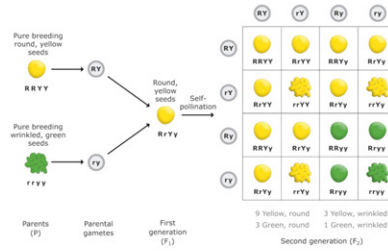
Gregor Johann Mendel (1822-1884)



Versuche über Pflanzen-Hybriden (1865)

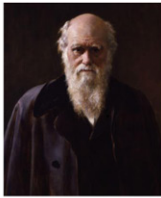
멘델의 법칙 (Mendelian inheritance)

- 우열의 법칙 (Law of Dominance)
- 분리의 법칙 (Law of Segregation)
- 독립의 법칙 (Law of Independent Assortment)

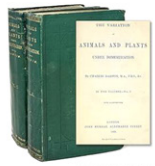


가축화 형질의 유전적 해석

가축화와 형질 차이의 관찰



Charles Robert Darwin (1809-1882)



(Charles Darwin, 1868)

The nature of the food supplied during many generations has apparently affected the length of the intestines; for, according to Cuvier,<sup>29</sup> their length to that of the body in the wild boar is as 9 to 1,—in the common domestic boar as 13.5 to 1,—and in the Siam breed as 16 to 1. In this latter breed the greater

형질 관련 좌위 탐색

Genetic Mapping of Quantitative Trait Loci for Growth and Fatness in Pigs

Leif Andersson,\* Chris S. Haley, Hans Ellegrøn, Sara A. Knott, Maria Johansson, Kjell Andersson, Lena Andersson-Eklund, Inger Edfors-Lilja, Merete Fredholm, Ingemar Hansson, Jan Håkansson, Kerstin Lundström

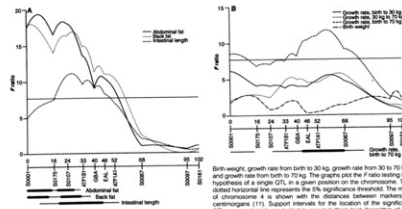
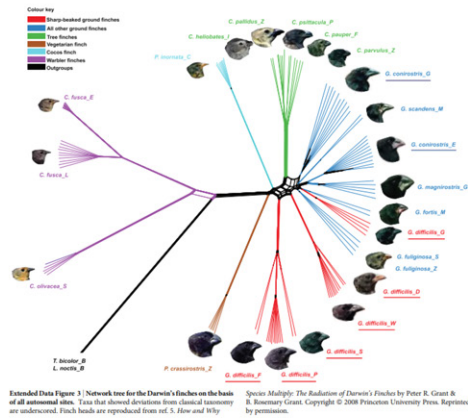


Fig. 1. Test statistic curves for chromosome 4. (A) Abdominal fat percentage, average back fat depth, and length of the small intestine. (B)

(Andersson L et al., 1994)

다윈 핀치와 유전체 분석



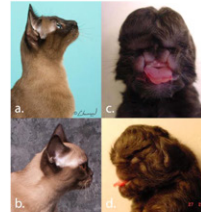
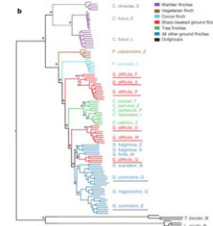
ARTICLE

Evolution of Darwin's finches and their beaks revealed by genome sequencing

Support: Louis Bernatchez<sup>1,2</sup>, Anne Berglund<sup>1,2</sup>, Nathan Williams<sup>1,2,3</sup>, Thomas Bagstad<sup>1</sup>, Robert Lindstedt<sup>1</sup>, Brian Hartman<sup>1</sup>, Sara Schreiber<sup>1</sup>, Carl Gustaf Bergström<sup>1</sup>, Ole Frank<sup>1</sup>, Anders Carlsson<sup>1</sup>, A. Benjamin Cooper<sup>1,4</sup>, Peter R. Grant<sup>5</sup>, Rosemary B. Grant<sup>5</sup>, and Lars Andersson<sup>1,2</sup>

Darwin's Finches, including the Galapagos and Cocos Island, constitute an iconic model for studies of speciation and adaptive radiation. Here we report the complete genome, gene-level annotation and transcriptome sequencing of all 18 Darwin's finches and their closest relatives. We identify 100 million single nucleotide polymorphisms (SNPs) and 100,000 genes. We find extensive evidence for divergence in gene flow throughout the radiation. We also identify 100 genes that are upregulated in beak tissue. We identify 100 genes that are downregulated in beak tissue. We identify 100 genes that are upregulated in beak tissue. We identify 100 genes that are downregulated in beak tissue. We identify 100 genes that are upregulated in beak tissue. We identify 100 genes that are downregulated in beak tissue.

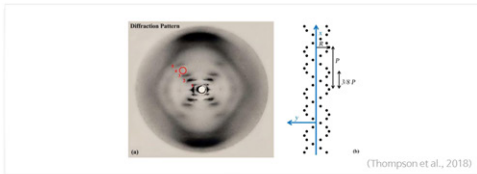
(Lamicharney et al., 2015)



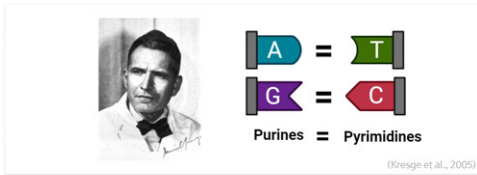
이후 확인된 ALX1 유전자의 영향  
(Lyons et al., 2016)

DNA (Deoxyribonucleic Acid) 구조의 발견

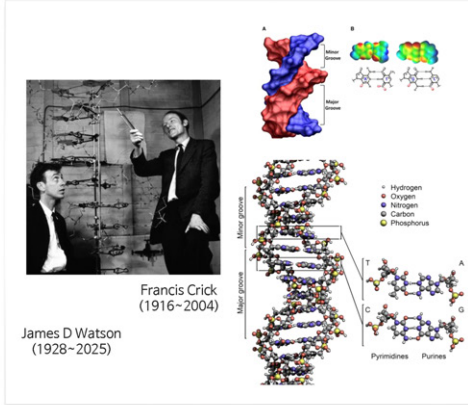
Rosalind Franklin의 X선 회절 사진



사카프의 법칙 (Chargaff's rules)



DNA 이중나선 구조의 발견



03 개인 유전체 분석 시대의 시작



Published online 1 June 2007 | Nature | doi:10.1038/news070528-10

News  
**James Watson's genome sequenced**

Discoverer of the double helix blazes trail for personal genomics.

Erika Check

Nobel laureate James D. Watson peered deep into his genome yesterday. And soon, anyone else interested in his genetic makeup will be able to do the same.

Scientists in Houston presented Watson with a DVD of his genome sequence, which they said was the "first individual genome to be sequenced for less than \$1 million". The carefully worded claim may be an acknowledgement that another personal genome project has already been completed: J. Craig Venter has deposited his genome sequence into the public GenBank database, he told *Nature* two weeks ago.

Such personal genomes are for now largely symbolic, because it's difficult to



James Watson is the first individual sequenced for less than million.

National Library of Medicine

Table 3 | SNPs matching HGMD mutations causing disease or other phenotypes

HGMD accession	Chromosome	Coordinate	HUGO symbol	Gene name	Cytogenetic	Phenotype	Zygosity
CM003589	1	97937679	DPYD	Dihydropyrimidine dehydrogenase	1q22	Dihydropyrimidine dehydrogenase deficiency	Heterozygous
CM950484	1	157441978	FY	Duffy blood-group antigen	1q	Duffy blood group antigen, absence	Homozygous*
CM942034	4	619702	PDE6B	Phosphodiesterase 6B, cGMP-specific, rod, beta	4p16.3	Retinitis pigmentosa 40	Heterozygous
CM021718	9	36208221	GNE	UDP-N-acetylglucosamine 2-epimerase	9p	Myopathy, distal, with rimmed vacuoles	Heterozygous
CM980633	10	50348375	ERCC6	Excision repair cross-complementing rodent repair deficiency, complementation group 6 protein (CSB)	10q	Cockayne syndrome	Homozygous†
CM050716	11	76531431	MYO7A	Myosin VIIA	11q13.5	Usher syndrome 1b	Homozygous†
CM950928	12	46812979	PFKM	Phosphofructokinase, muscle	12q13.3	Glycogen storage disease 7	Homozygous*
CM032029	14	20859880	RPGRP1	Retinitis pigmentosa GTPase regulator interacting protein 1	14q11	Cone-rod dystrophy	Heterozygous
CM984025	19	18047618	IL12RB1	Interleukin-12 receptor, beta 1	19p13.1	Mycobacterial infection	Heterozygous
CM024138	19	41014441	NPHS1	Nephrosis-1, congenital, Finnish type	19q	Congenital nephrotic syndrome, Finnish type	Heterozygous
CM910052	22	49410905	ARSA	Arylsulphatase A	22q	Metachromatic leukodystrophy	Heterozygous

\* Coverage at these SNP positions is less than 5. However, both produce benign phenotypes.  
† Coverage at these SNP positions is greater than 5. Both would produce severe phenotypes if they were truly homozygous.

(Wheeler et al., 2008)



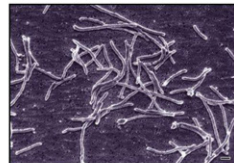
James D. Watson (1928-2025)

03 PCR 기술과 DNA marker 분석의 발전

호열성 세균의 발견



Thomas D. Brock (1926-2021)

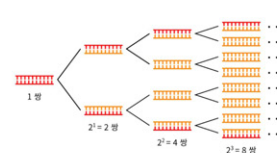


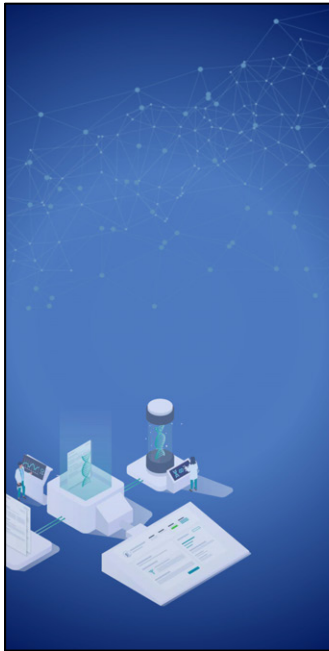
호열성 세균 (Thermus aquaticus)

PCR의 발견



Kary B. Mullis (1944-2019)





Chapter 01 재래가축의 가치와 가축유전학의 출발

Chapter 02 마커와 유전체로 읽는 재래가축의 유전적 가치

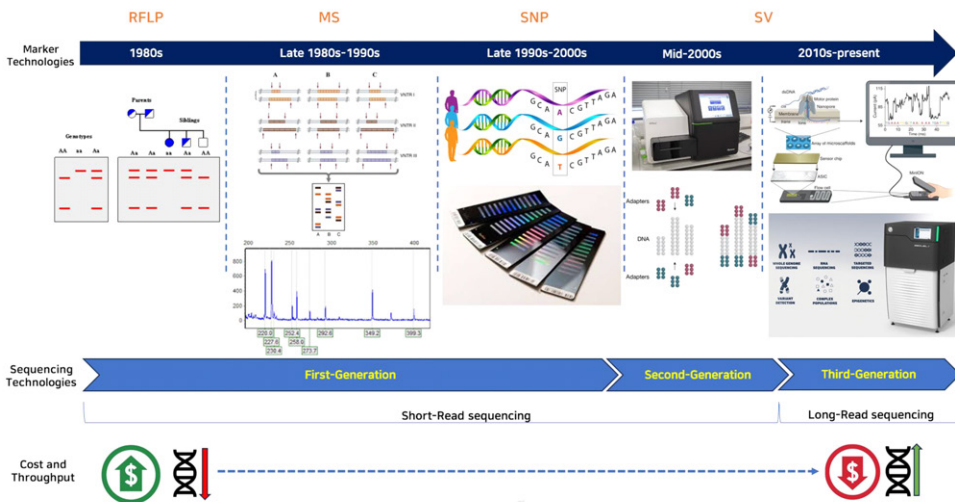
Chapter 03 예측과 설계로 확장되는 가축유전학

Chapter 04 유전정보가 이끄는 지속가능한 축산



Chapter 02 마커와 유전체로 읽는 재래가축의 유전적 가치

가축유전학의 과거, 현재, 그리고 미래



유전적 식별과 계통 관리 01

- 성 감별
- 친자 감정
- 개체 식별 및 집단 구분

형질 관련 변이 탐색 02

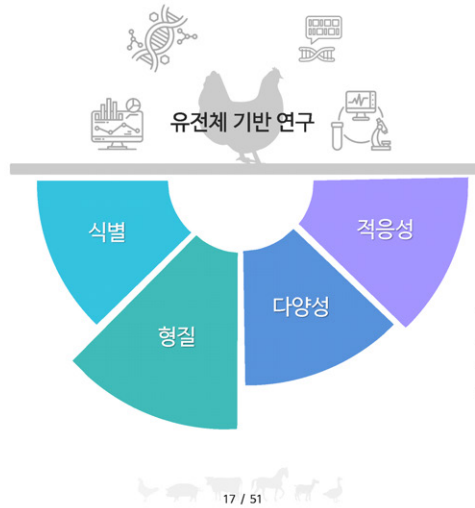
- 경제형질 마커
- QTL mapping
- GWAS

유전적 적응성과 면역 다양성 04

- 선발신호
- MHC

유전적 다양성과 집단 구조 03

- Genetic diversity
- PCA
- ADMIXTURE



반성유전을 이용한 성 감별 (Sex-linked inheritance)

유전적 식별과 계통 관리 01

- 성염색체 (Z/W)에 위치한 유전자 차이를 이용하여 깃털 성장 속도로 암수 구분이 가능

조우성과 만우성을 이용한 성감별



(Kwon et al., 2021)

한국가축학회지 제 28호, 117-125 (2024)  
Korean J. Poult. Sci. Vol. 51, No. 2, 117-125 (2024)  
<https://doi.org/10.5388/KJPS.2024.51.2.117>

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Identification and Characterization of Novel Sequences of *ex21-K* Locus for Feather-Sexing in Chickens

Eun Jung Cho<sup>1</sup> and Sea Hwan Solar<sup>2\*</sup>

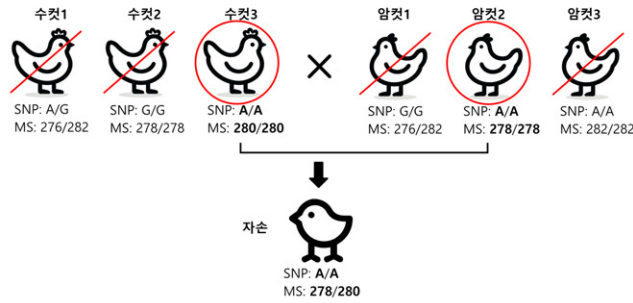
<sup>1</sup>Researcher, Division of Animal Bioscience and Integrated Biotechnology, Geongsang National University, Jinju 52725, Republic of Korea

<sup>2</sup>Professor, Division of Animal Bioscience and Integrated Biotechnology, Geongsang National University, Jinju 52725, Republic of Korea

유전 마커를 이용한 친자 감정

유전적 식별과 계통 관리 01

- 자손 개체와 부모 개체의 유전자형 비교 분석으로 친자관계 확인



유전 마커를 이용한 친자 감정

유전적 식별과 계통 관리 01

- 자손 개체와 부모 개체의 유전자형 비교 분석으로 친자관계 확인

MS marker

친자 확인 관리시스템

친자 감정 서비스

SNP marker

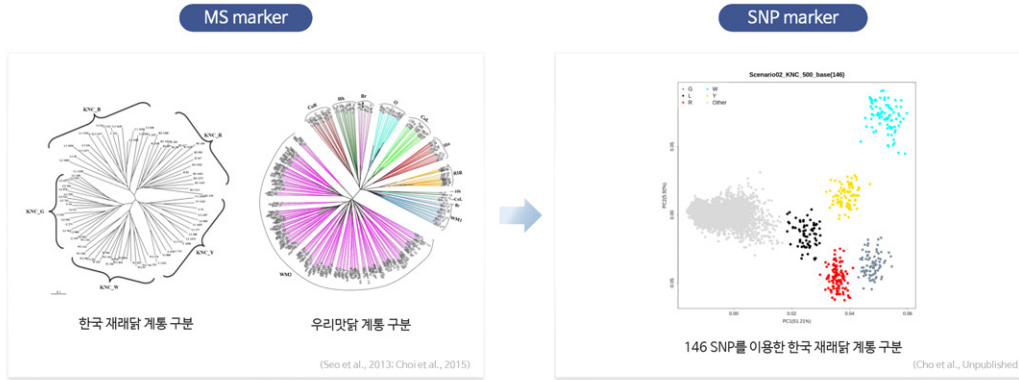
다양한 집단에서의 친자 감정

(Strucken et al., 2016)

유전 마커를 이용한 개체 및 집단 식별

유전적 식별과 계통 관리 01

- 유전 마커를 이용하여 품종 및 집단을 정확하게 식별 가능



경제형질 연관 마커 데이터 베이스의 활용

형질 관련 변이 탐색 02

- 대규모 데이터 베이스를 활용하여 경제형질 연관 마커 확인

**Aniaml QTLdb**

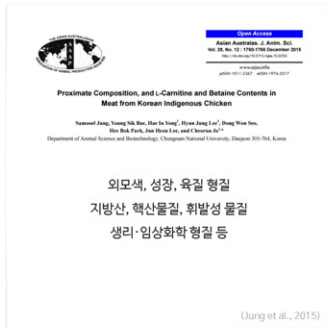
**OMIA (Online Mendelian Inheritance in Animals)**

경제형질 연관 QTL mapping

형질 관련 변이 탐색 02

- 경제형질 연관 표현형 측정 및 QTL 탐색

표현형 확보



유전적 연관지도 작성



QTL mapping

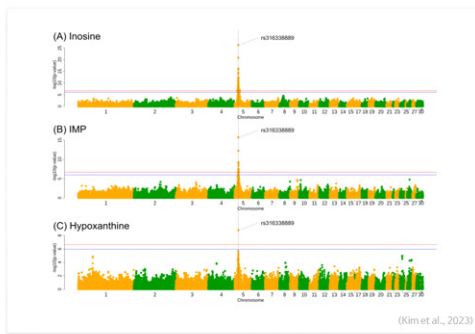


형질 관련 유전변이 탐색 (GWAS)

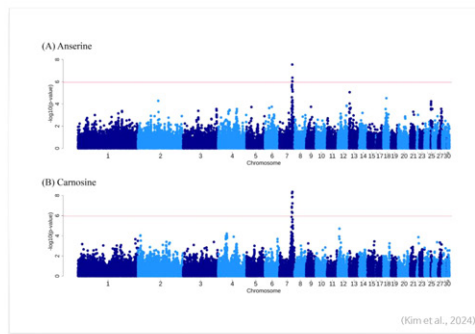
형질 관련 변이 탐색 02

- GWAS를 통해 다양한 형질과 연관된 유전체 영역 발굴

풍미 관련 핵산물질



풍미 관련 펩타이드



형질 관련 유전변이 탐색 (GWAS)

형질 관련 변이 탐색 02

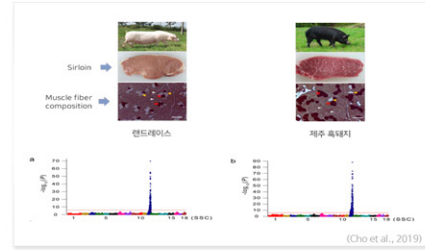
- GWAS를 통해 다양한 형질과 연관된 유전체 영역 발굴



피모색



육질

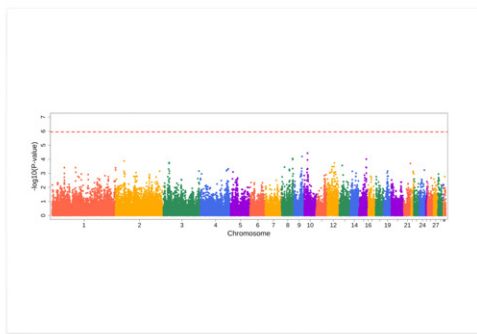


형질 관련 유전변이 탐색 (GWAS)

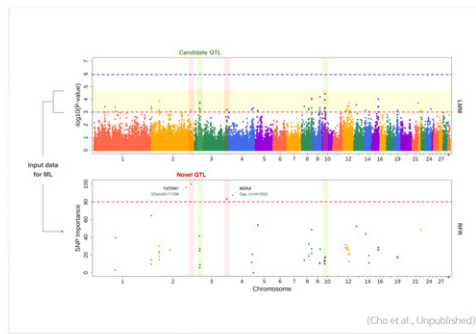
형질 관련 변이 탐색 02

- GWAS와 머신러닝의 융합을 통한 형질 관련 유전변이 탐색

기존 GWAS



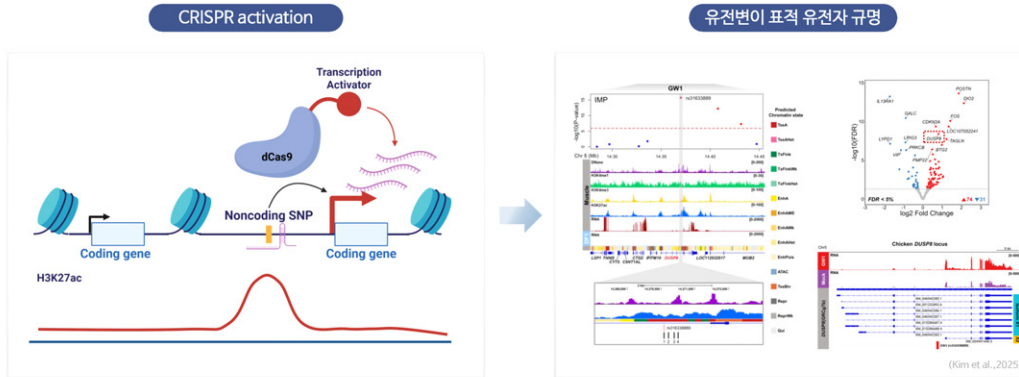
ML-GWAS



형질 관련 유전변이 탐색 (GWAS)

형질 관련 변이 탐색 02

- GWAS로 발굴한 형질 연관 유전변이의 CRISPR 기반 기능 검증



SNP marker 기반 한국 재래닭의 유전적 위치와 집단 구조 분석

유전적 다양성과 집단 구조 03

- 전 세계 닭 집단을 포함하는 SYNBREED diversity panel 활용

Malomane et al. BMC Genomics (2019) 20:345  
https://doi.org/10.1186/s12864-019-5722-9

BMC Genomics

RESEARCH ARTICLE Open Access

The SYNBREED chicken diversity panel: a global resource to assess chicken diversity at high genomic resolution

Dorcus Kholofelo Malomane<sup>1,2</sup>, Henner Simianer<sup>1,2</sup>, Annett Weigend<sup>1</sup>, Christian Reimer<sup>1,2</sup>, Armin Otto Schmitz<sup>1,2</sup> and Steffen Weigend<sup>1,2\*</sup>

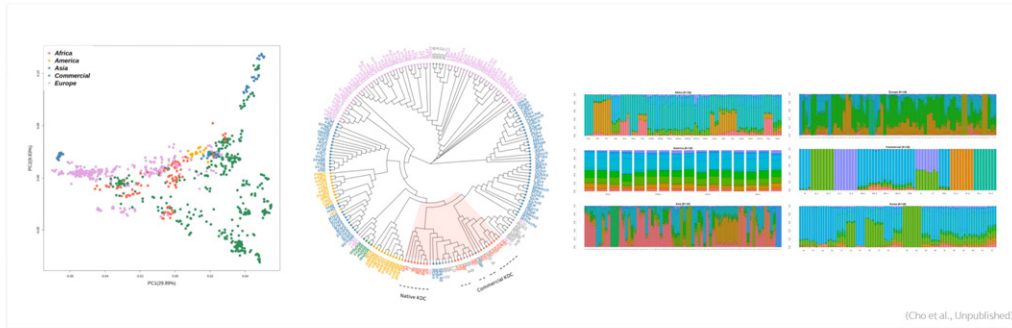
Steffan Weigend

● SNP marker 기반 한국 재래닭의 유전적 위치와 집단 구조 분석

유전적 다양성과 집단 구조 03

- 전 세계 닭 집단과의 비교를 통해 한국 재래닭의 유전적 위치를 확인

집단 구조 분석



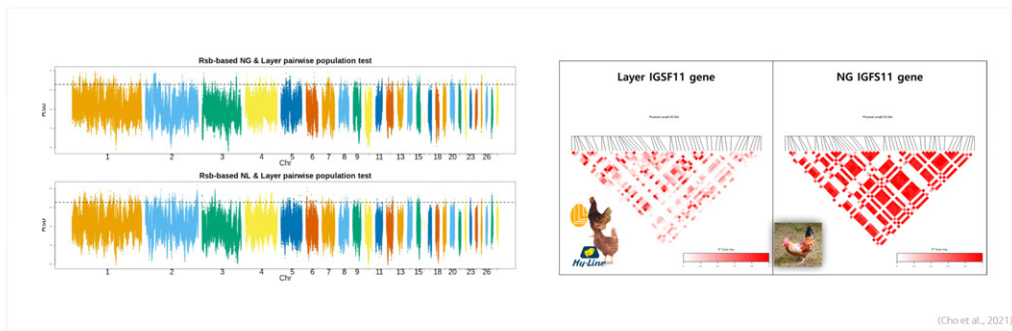
(Cho et al., Unpublished)

● 선발신호 분석 (Selection signature analysis)

유전적 적응성과 면역 다양성 04

- 선발에 의해 특정 유전변이가 집단 내에 축적된 패턴 탐색

한국 재래닭과 실용계 비교



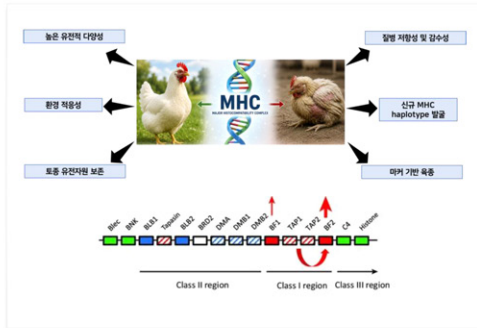
(Cho et al., 2021)

주조직적합복합체 (MHC)

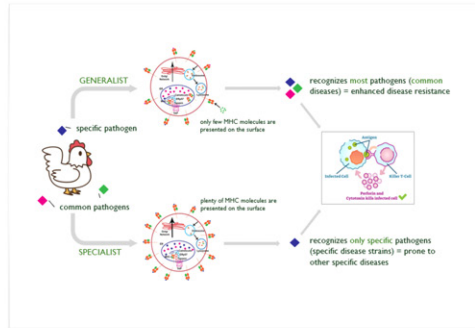
유전적 적응성과 면역 다양성 04

- 적응면역계에 필수적인 세포 표면 단백질을 암호화하는 유전자들의 집합

연구 필요성



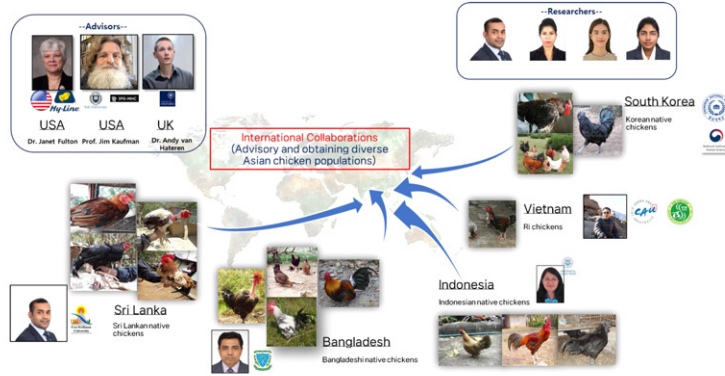
MHC haplotype



주조직적합복합체 (MHC)

유전적 적응성과 면역 다양성 04

- 재래닭 MHC-B 다양성 분석을 위한 국제 공동연구

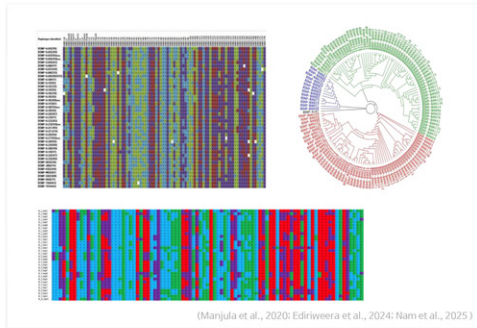


주조직적합복합체 (MHC)

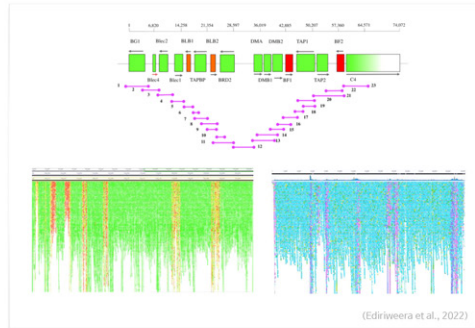
유전적 적응성과 면역 다양성 04

MHC-B 다양성 및 Haplotype 규명

MHC haplotype 다양성



NGS 기반 MHC haplotype 규명

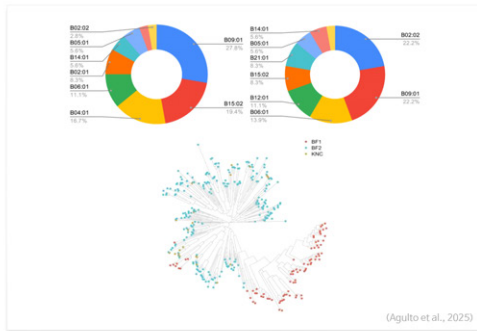


주조직적합복합체 (MHC)

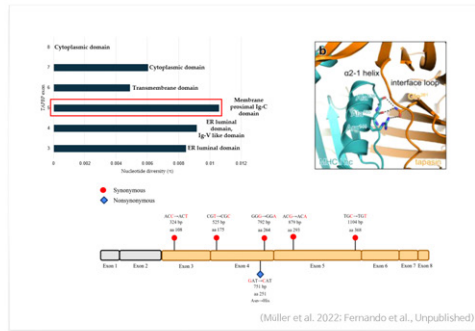
유전적 적응성과 면역 다양성 04

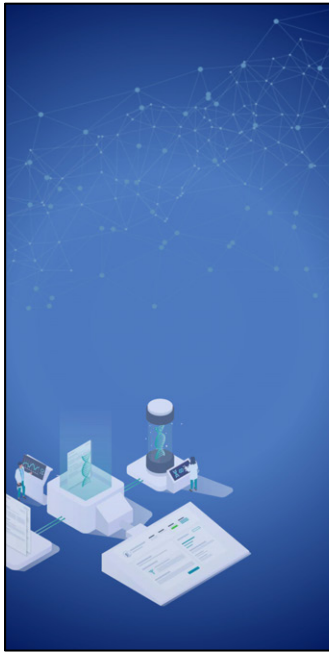
MHC Class I (B2) 및 TAPBP 유전자의 유전적 특성 분석

B2 유전자



TAPBP 유전자





Chapter 01 재래가축의 가치와 가축유전학의 출발

Chapter 02 마커와 유전체로 읽는 재래가축의 유전적 가치

Chapter 03 예측과 설계로 확장되는 가축유전학

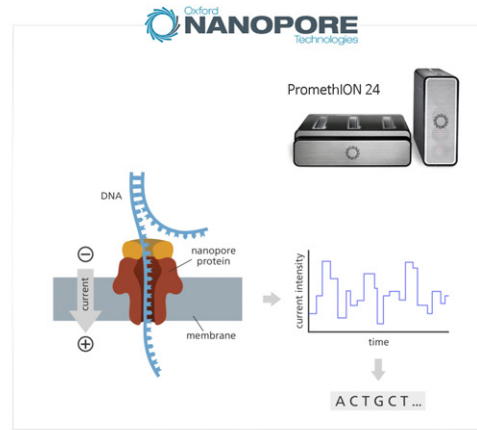
Chapter 04 유전정보가 이끄는 지속가능한 축산



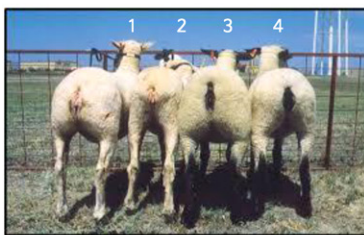
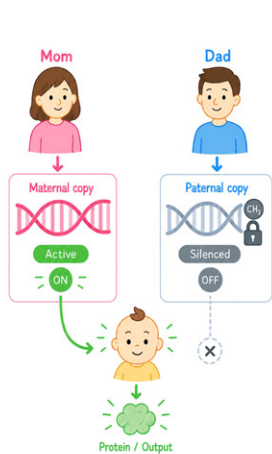
Chapter 03 예측과 설계로 확장되는 가축유전학

가축유전학의 과거, 현재, 그리고 미래

Sequencing의 발달



유전체 각인 (Genomic Imprinting)

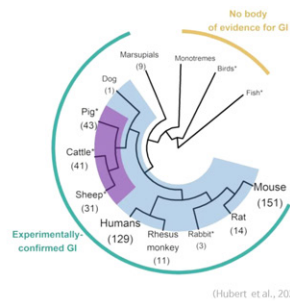


정상 개체 (2와 4)와 비교한 callipygous 개체 (1과 3)의 표현형 (Cockett et al., 2006)

geneimprint

Imprinted Genes: by Species

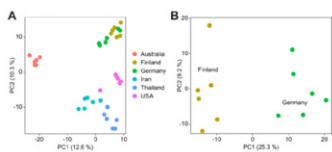
Gene	Location	Species	Imprinted	Experimental status
MEG8	12q15	Human	Imprinted	Paternal
MEG1	15q11	Human	Imprinted	Paternal
MEG3	15q11	Human	Imprinted	Paternal



(Hubert et al., 2024)

Imprinting detection: EpiTrace™ technology

Proof of concepts EpiTrace™



Chicken (*Gallus gallus*)

Farm-dependent epigenetic signatures in chicken. (A) Principal component analysis of samples from 6 different chicken farms, based on the methylation levels of 8215 CpG sites with farm-specific methylation differences. (B) Principal component analysis of samples from Finland and Germany, based on the methylation levels of 5887 CpG sites with location-specific methylation differences in a pair-wise analysis.



2024.01 방문



For Research Use Only. Not for use in diagnostic procedures.

23andMe (Trait Reports)

23andMe website interface showing a report for Type 2 Diabetes with a 37% likelihood. The report lists 33 traits associated with the user's genetics.

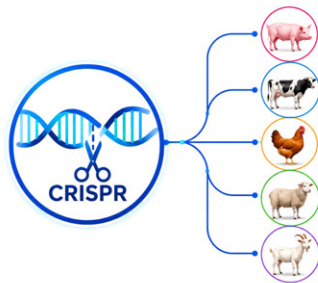
1. 음높이 맞추는 능력
2. 아스파라거스 냄새 감지
3. 등 털 (남성 전용)
4. 장수리 탈모 (남성 전용)
5. 손맛 민감도
6. 무지외반증
7. 뺨 보조개
8. 고수 맛 거부감
9. 갈라진 턱
10. 비듬
11. 귤불 유형
12. 조기 탈모 (남성 전용)
13. 귀지 유형
14. 눈 색
15. 고소 공포증
16. 대중 연설에 대한 두려움
17. 손가락 길이 비율
18. 평발
19. 쿠근개
20. 햇빛에 의한 모발 탈색
21. 모발 형태
22. 머리카락 굵기
23. 아이스크림 맛 선호도
24. 밝은 머리색 또는 어두운 머리색
25. 미소포니아 (섬는 소리 혐오감)
26. 모기 물림 빈도
27. 멀미
28. 신생아 머리술
29. 빛 재채기 반사
30. 붉은 머리
31. 피부 색소 침착
32. 툰살
33. 달콤 vs. 짠맛 선호도
34. 발가락 길이 비율
35. 일자 눈썹
36. 기상 시간
37. M자 이마 라인

(23andMe, <https://www.23andme.com/>)

(Fox news, 2025)

(Macrogen, <https://www.macrogen.com/>)

Genome editing: CRISPR-Cas9



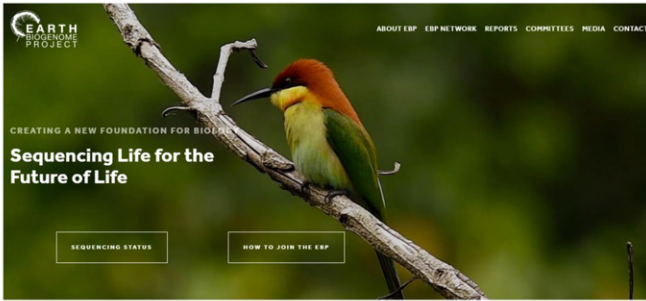
Genome editing results and applications:

- a** Gel electrophoresis results for CRISPR-Cas9 editing in chickens. Lanes include: Size (bp), RC1-001, RC2-002, RC3-003, RC4-004, p1748, and Holohep. Molecular weight markers are shown on the left (900, 700, 600, 500, 400, 300 bp).
- b** Gel electrophoresis results for CRISPR-Cas9 editing in cattle. Lanes include: Size (bp), RC1-001, RC2-002, RC3-003, RC4-004, p1748, and Holohep. Molecular weight markers are shown on the right (3,000, 2,500, 2,000, 1,500, 1,000 bp).
- c** Image of a genome-edited hornless dairy cow. (Carlson et al., 2016)
- d** Image of genome-edited PRRS-resistant pigs. (<https://www.pic.com/pic-prrs-resistant-pig/>)

Genome-edited AI resistant chicken (Idoko-Alsch et al., 2023)

Genome-edited PRRS-resistant pig (<https://www.pic.com/pic-prrs-resistant-pig/>)

Earth BioGenome Project (EBP)



What is the Earth BioGenome Project?

Powerful advances in genome sequencing technology, informatics, automation, and artificial intelligence, have propelled humankind to the threshold of a new beginning in understanding, utilizing, and conserving biodiversity. For the first time in history, it is possible to efficiently sequence the genomes of all known species, and to use genomics to help discover the remaining 80 to 90 percent of species that are currently hidden from science.

(<https://www.earthbiogenome.org/>)



Harris Lewin  
(Arizona State University)

“지구상 진핵생물 유전체를 참조 수준으로  
해독하는 글로벌 프로젝트”

Phase II 전략

1. Adaptive sampling
2. Highest genome quality
3. Equitable global partnerships



Pangenome

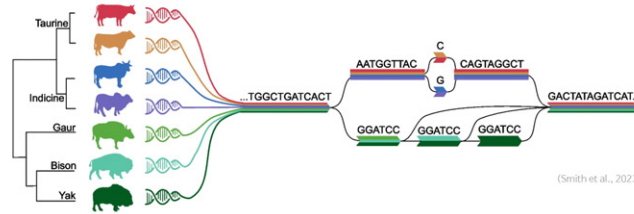


The Bovine Pangenome Consortium

The official information page for the consortium and its members

The Bovine Pangenome Consortium is an international research consortium dedicated to the sequencing and assembly of bovid species for research applications. We are comprised of experts in the field of Genetics, Genomics, Bioinformatics and Animal Science from countries throughout the world.

(<https://bovinepangenome.github.io/>)



(Smith et al., 2023)



AI 대전환



Geoffrey Hinton  
(2024 Nobel Prize in Physics)

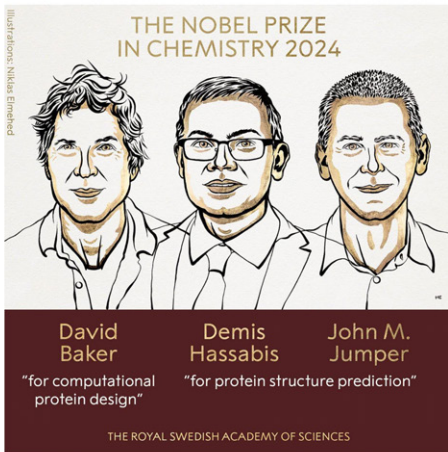
인공신경망 연구

Massive training set of genome

-> AI driven discovery

-> AI driven application

AI 대전환



David Baker  
Demis Hassabis  
John M. Jumper  
(2024 Nobel Prize in Chemistry)

AI 기반 단백질 구조 예측



AI 대전환

AlphaGenome  
AlphaFold

AlphaGenome API  
AlphaFold

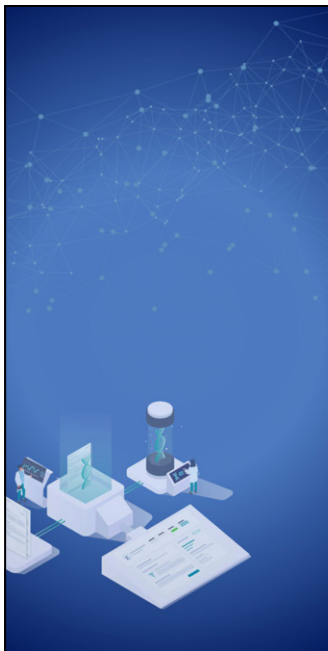
(<https://deepmind.google.com/science/alphagenome/>)  
(<https://deepmind.google/science/alphafold/>)

Arc  
Evo2

Application layer: Prediction (Genetic variant effects, Protein mutational scanning, mRNA mutational scanning, RNA stability/toxicity, Regulatory element feature ID), Design (Genomic scale generation, Protein complex generation, Exon classification Splicing variant effects, Chromatin accessibility combinatorial generation)

Foundation layer: DNA, RNA, Protein

(<https://arcinstitute.org/tools/evo/>)



- Chapter 01 재래가축의 가치와 가축유전학의 출발
- Chapter 02 마커와 유전체로 읽는 재래가축의 유전적 가치
- Chapter 03 예측과 설계로 확장되는 가축유전학
- Chapter 04 유전정보가 이끄는 지속가능한 축산

Summary

1. 유전자원 보존

재래가축은 미래 육종을 위한 유전적 자원

2. 유전정보 기반 해석

식별·형질·다양성·적응성 분석을 통한 가치 규명

3. 지속가능한 축산

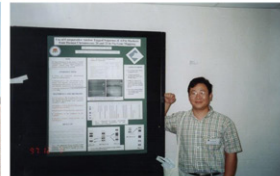
유전체 정보와 AI·유전체 편집·판지놈 기술과의 융합

가축유전학은 재래가축의 보존을 넘어, 미래 축산의 설계 도구로 확장되고 있다.



Acknowledgement

- PhD period (1997-2001) and after



ISAG 2004 Tokyo



Sydney 2013



AAAS 2024 Melbourne

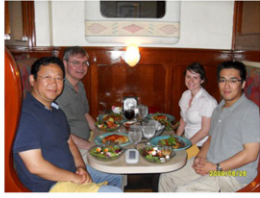


ISAG 2025 Daejeon



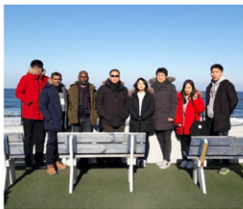
Acknowledgement

- Academic supervisors, mentors and colleagues



Acknowledgement

- Past and present students



# 가축유전학의 과거, 현재, 그리고 미래

(Animal Genetics: Past, Present, and the Future)

2026년도 한국축산학회 국제연합심포지엄 및 학술발표회  
2026. 07. 09.

이준현

## Thank you

충남대학교 농업생명과학대학 동물자원생명과학과 교수  
충남대학교 연구처장 / 산학협력단장



# Plant Fiber Digestion, an Animal Scientist's Journey from the Cow Rumen to the Human Gut

**Isaac Cann**

(University of Illinois  
Urbana-Champaign, USA)

## Curriculum Vitae

Isaac Cann received his PhD in 1994 from Mie University, Japan. He is currently a Professor of Animal Science and the Institute for Genomic Biology, University of Illinois Urbana-Champaign (UoI), USA. Before joining UoI, he was Senior Research Scientist at Biomolecular Engineering Research Institute (Japan) and Visiting Scientist at New England Biolabs (USA). His research interests include fiber digestion in ruminants and humans, microbial enzymes for bioenergy production, DNA replication in methanogens, and impact of microbiomes on host health. He is a recipient of the prestigious National Science Foundation Career Award and served on the Committee on Metagenomics (National Academies) and as Deputy Director of the Energy Biosciences Institute. He has published in many high impact journals, serves as editor for Applied and Environmental Microbiology and Annual Review of Animal Biosciences and is an elected fellow of both American Academy of Microbiology and American Association for the Advancement of Science.



# Fiber Digestion, a Journey from the Cow Rumen to the Human Gut

Plants harvest and store energy from sunlight in the form of structural carbohydrates, significant being cellulose, hemicellulose, and pectin. Due to their critical roles in plants, including providing strength and protection, these structural polysaccharides are recalcitrant to degradation. As an example, cellulose is reported as having a half-life in millions of years at 25°C. Ruminant animals have, however, evolved a complex community of microbes that deploy a vast array of enzymes in their foregut to release fermentable sugars from these polysaccharides. Rumen microbial fermentation of polysaccharides leads to microbial cell proliferation and short chain fatty acids, the major sources of protein and energy, respectively, for the host animal. Genomic and transcriptomic analyses, from our group and others, have yielded the molecular determinants underlying microbial interactions for efficient plant fiber degradation and fermentation in the rumen. In this process, the microbes enlist diverse plant cell wall degradation mechanisms, including the polysaccharide utilization loci (PULs) and cellulosomal paradigms, in accessing the energy trapped in plant fibers. Investigation of the product of a newly discovered hemicellulose-targeting gene, in the rumen bacterium *Prevotella bryantii*, led to the observation that ruminants and humans share xylan degradation strategies. This discovery enhanced our interest to understand the physiological basis of fiber fermentation by human colonic bacteria. Fascinatingly, we discovered that the human colonic *Bacteroides* spp., belonging to the same phylum as the cow rumen *Prevotella* spp., employ not only similar strategies but also similar enzymes to depolymerize arabinoxylan, a common hemicellulose found in human diets. Colonic fiber fermentation contributes to caloric intake of the human host; however, insights from our mechanistic studies also suggest significant health benefits. Our results unravel important attributes of fiber in the diet that with better understanding can be extended to enhance sustainability of both ruminant and monogastric animal production.





# Understanding the Diversity and Roles of the Pig Gut Microbiome

김 현 범  
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## Curriculum Vitae

- ▶ 2014~현재 단국대학교 동물생명공학 교수
- ▶ 2012~2014 미국 Tufts 대학교 박사후 연구원
- ▶ 2008~2012 미국 미네소타주립대 박사(Microbiome & Metagenomics)
- ▶ 2006~2008 미국 미네소타주립대 석사(수의미생물학)
- ▶ 2000~2003 농협중앙회
- ▶ 1993~2000 충남대학교 수의학 학사



# Understanding the Diversity and Roles of the Pig Gut Microbiome

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The pig gastrointestinal tract (GIT) harbors a complex, dynamic, and dense microbial ecosystem, collectively known as the gut microbiome, which plays a foundational role in host health, metabolic homeostasis, and overall swine production efficiency. Phylogenetically, the pig gut is heavily dominated by the phyla Firmicutes and Bacteroidota, though its composition shifts drastically along the longitudinal axis of the GIT, dictated by local physiological gradients such as pH, digesta transit time, and oxygen availability. Temporal successions are equally pronounced. The transition during the weaning period represents a critical developmental window characterized by sharp microbial dysbiosis, making piglets highly susceptible to post-weaning diarrhea caused by pathogens like enterotoxigenic *Escherichia coli*. Functionally, the swine microbiome acts as a critical metabolic organ. It breaks down non-digestible dietary carbohydrates via fermentation to produce short-chain fatty acids (SCFAs), principally acetate, propionate, and butyrate, which serve as primary energy sources for colonocytes and modulate systemic energy metabolism. Beyond nutrition, the microbiota is indispensable for the structural maturation of gut-associated lymphoid tissue (GALT), the regulation of mucosal immunity, and the maintenance of intestinal barrier integrity through the competitive exclusion of pathogens. Ultimately, a deeper mechanistic understanding of these host-microbiota interactions provides a roadmap for precision nutrition.



## 중견 & 신진과학자 세션





# Philosophy of Animal Welfare and Application of Animal Behavior

전 중 환

Jeon, Jung Hwan

(강원대학교)

(Kangwon National University)

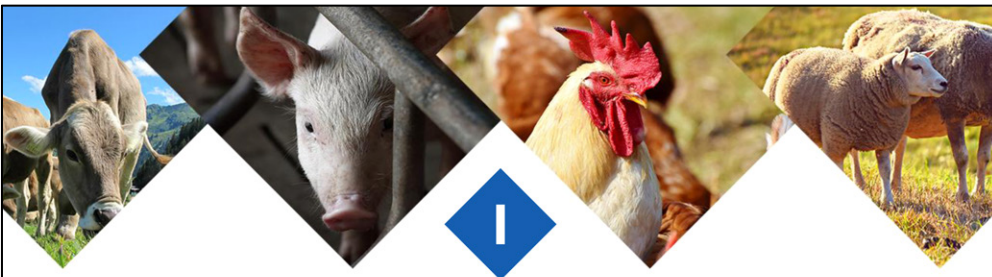
## Curriculum Vitae

- ▶ 2026~현재 강원대학교 동물산업융합학과 교수
- ▶ 2021~2026 농진청 국립축산과학원 농업연구관
- ▶ 2007~2021 농진청 국립축산과학원 농업연구사
- ▶ 2006~2007 University of British Columbia Post-Doc.
- ▶ 2003~2006 경상대학교 대학원 응용생명과학부 이학박사
- ▶ 2001~2003 경상대학교 대학원 응용생명과학부 이학석사
- ▶ 1994~2001 경상대학교 축산학과 농학사



# 동물복지의 철학과 동물행동의 응용

강원대학교  
동물산업융합학과  
전 중 환



## 철학의 변화

## 반려동물에 대한 가치성의 재인식

— ◆ 인간과 더불어 살아가고 교감하면서 반려자 혹은 친구로서 존중

- 반려동물과의 교감은 인간본연의 성정을 찾는데 많은 도움을 줌



사람을 구한  
반려동물



사람에 의해 고통 받는  
반려동물



## 전시동물은 과연 동물학대인가?

— ◆ 동물원의 동물은 오락과 더불어 교육의 기능을 가지며,  
동물을 이용한 경기 등이 전통이나 축제로 자리 잡고 있음

- 전통문화의 계승인가? 동물학대인가? 논란은 진행 중..



창설 없는 동물원 하겐베르크

▷ 하겐베르크는 독일의 유명한 동물원 이름이자 그 동물원을 만든 사람의 이름으로 최초로 현대적 의미의 동물원을 만들었으며 나중에 창설이 없는 '생태 동물원'으로 개량하여 유명해짐

## 실험동물의 이용과 윤리



### ◆ 인간의 안전과 과학의 발전을 위해 동물이용실험에 이용

- 동물 종(種) 사이의 차이에 따른 동물이용실험의 신뢰성 문제

- 3R원칙 :

Replacement(대체사용법 강구), Reduction(실험동물 수의 축소), Refinement(고통의 최소화)

#### 드레이즈 시험(Draize test)

▷ 화학물질(약물, 세제, 화장품 등)의 눈에 대한 자극성을 실험하는 방법

- 1940년대 드레이즈(J. H. Draize)에 의해 개발됨

- 눈물의 양이 적은 알비노 토끼의 눈에 직접 화학물질을 넣어 부작용을 실험함

- 토끼가 움직이지 못하게 고정한 채로 수일간 지속해서 실험함



## 생물다양성 보존을 위한 야생동물 보호



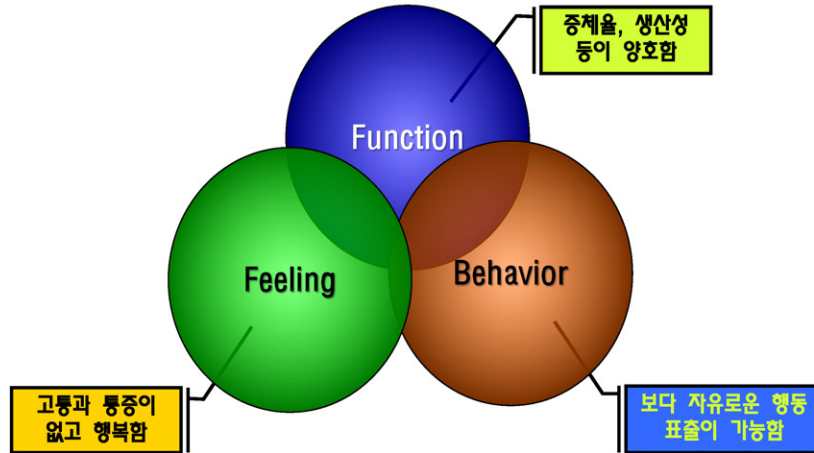
### ◆ 무분별한 밀렵, 남획 및 서식지 감소로부터 동물을 보호

- 과거 200년 동안 100여종의 포유류, 160여종의 조류가 인위적으로 멸종됨



## 농장동물의 복지는 무엇이 문제인가?

◆ 농장동물의 복지는 경제성을 포함하는 스트레스의 최소화



## 해외 동물복지 제도의 변화

◆ 동물학대 방지에서 동물 보호로 법률 확대

영국	미국	독일	일본
마틴법(1822), 동물보호법(1911), 동물복지법(1996)	28시간법(1873), 동물보호 연방기준 마련	제국동물보호법(1933), 동물보호법(1972)	동물보호관리법(1973), 동물애호관리법(1999)

◆ EU 동물복지 정책 추진

: 2012년부터 산란계 케이지 사용금지, 2013년부터 임신수를 사용금지

<p>FAWC(Farm Animal Welfare Council)에서는 농장동물 복지에 관한 의견제시</p>	<p>세계동물보건기구(OIE)에서는 가축의 동물복지 가이드라인 제정</p>	<p>UN에서는 동물복지가 모든 국가의 공통 목적이 되어야 함을 선언함</p>
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## 국내 동물복지 제도의 변화



## 동물복지의 철학

**스토아 학파 (Stoicism) :**  
 금욕과 평정을 최고선으로 규정

유물론과 심신론적 관점에서 금욕과 평정을 행하는 현자를 최고의 선

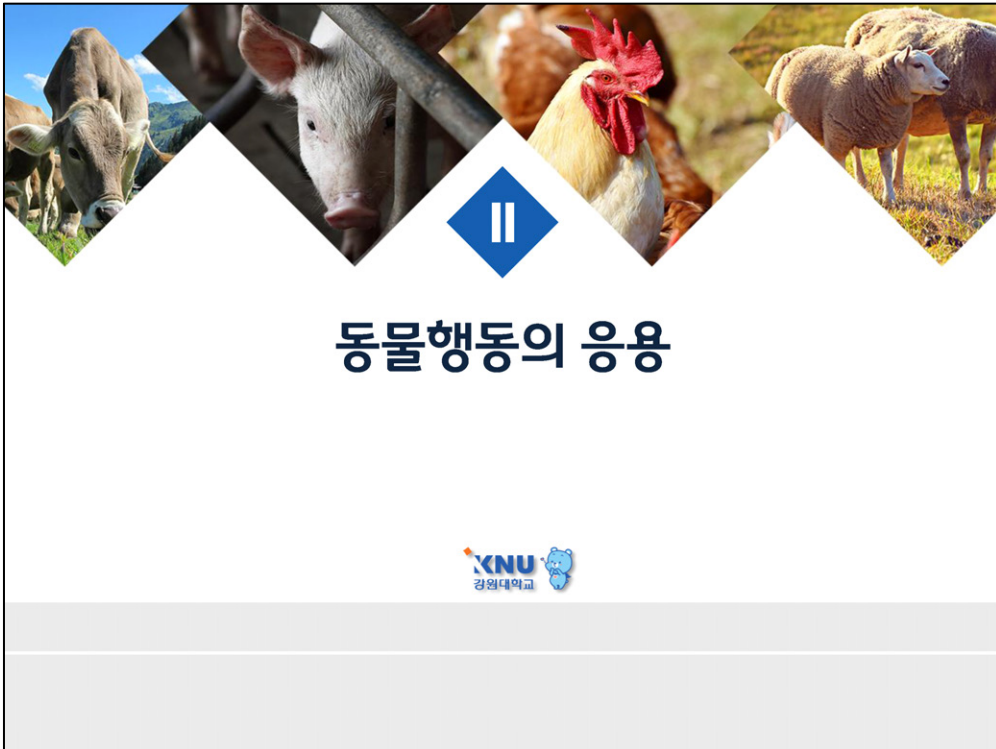


플라톤 (Plato)

아리스토텔레스 (Aristoteles)

“동물은 이성적이지 못하므로 이성을 지닌 인간이 동물을 배려해야 한다.”

“동물이 느끼는 고통에 대해 배려해야 한다 ”



**행동이란?**

KNU 강원대학교

## 왜 필요한가?



인간과 동물은 공통의 언어를 가지고 있지 않다.

## 케이지 사용금지에 따른 대안은?



기존의 케이지

평사사육



방사사육



다단식 사육시설

# 임신스틀 사용금지에 대한 대안은?



기존의 임신스틀

임신돈 군사장치 (Electronic sow feeder)



임신돈 군사시설 (Free access stall)

# 분만틀 사용금지에 대한 대안은?



기존의 분만틀

분만틀 대체 사육시설



방목사육

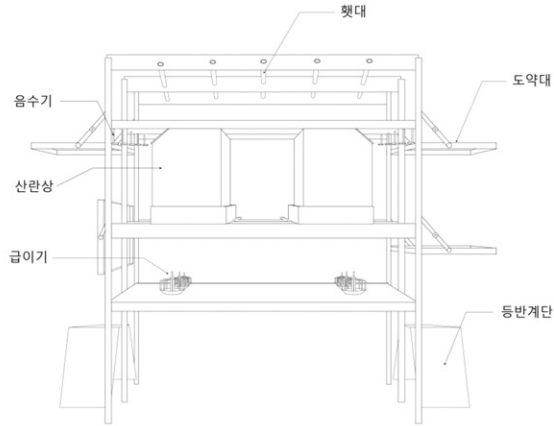
## 다단식 산란계 사육시설 (Multi-tier)



### 다단식 산란계 사육시설

- 동물복지 인증기준 충족 (급이기, 산란상, 햇대 제공 등)
- 산란율 8.2% 증가
- 오란 30%, 파란 60% 감소
- 노동시간 1/3 감소 ※평사 대비

### 능가보급 현황(26) : 13 set



- ✓ 해외 유사시설 대비 설치비용(1/4가격) 저렴 (설치비용: 6만원/수 → 1.5만원/수)
- ✓ 사후관리 및 기술지원 용이함
- ✓ 국내 사육여건을 반영하여 연구·개발

## 다단식 산란계 사육시설 (Multi-tier)

Table 1. Comparison of production performance between floor system and multi-tier system

Attribute and age	Housing system	
	Floor	Multi-tier
<b>Feed intake (g)</b>		
17-23 wk	106.93 ± 14.64 <sup>B</sup>	125.37 ± 21.96 <sup>A</sup>
24-30 wk	100.54 ± 26.54 <sup>B</sup>	123.22 ± 17.16 <sup>A</sup>
31-44 wk	103.09 ± 20.17 <sup>B</sup>	131.74 ± 28.49 <sup>A</sup>
<b>Egg production (%)</b>		
17-23 wk	65.99 ± 8.38 <sup>Bb</sup>	71.43 ± 9.14 <sup>Ab</sup>
24-30 wk	70.05 ± 1.82 <sup>Ba</sup>	80.15 ± 5.68 <sup>Aa</sup>
31-44 wk	70.89 ± 2.47 <sup>Ba</sup>	79.49 ± 4.49 <sup>Aa</sup>
<b>Cracked eggs (%)</b>		
17-23 wk	3.48 ± 0.73 <sup>Aa</sup>	1.38 ± 0.66 <sup>Ba</sup>
24-30 wk	1.83 ± 0.47 <sup>Ab</sup>	1.27 ± 0.34 <sup>Bab</sup>
31-44 wk	1.54 ± 0.29 <sup>Ac</sup>	1.14 ± 0.37 <sup>Bb</sup>
<b>Dirty eggs (%)</b>		
17-23 wk	4.08 ± 0.50 <sup>Aa</sup>	2.85 ± 1.03 <sup>Ba</sup>
24-30 wk	2.37 ± 0.40 <sup>b</sup>	2.12 ± 0.79 <sup>b</sup>
31-44 wk	1.64 ± 0.32 <sup>Ac</sup>	1.26 ± 0.72 <sup>Bc</sup>
<b>Mortality (%)</b>		
17-23 wk	0.00 ± 0.00	0.00 ± 0.00
24-30 wk	0.02 ± 0.06	0.01 ± 0.05
31-44 wk	0.01 ± 0.03	0.01 ± 0.05

# 다단식 산란계 사육시설 (Multi-tier)



Table 2. Comparison of egg quality in floor system and multi-tier system

Attribute and age	Housing system		
	Floor	Multi-tier	
Egg weight (g)	23 wk	53.98 ± 5.60 <sup>b</sup>	54.70 ± 3.87 <sup>c</sup>
	30 wk	54.93 ± 6.00 <sup>b</sup>	58.11 ± 4.08 <sup>b</sup>
	44 wk	64.99 ± 4.11 <sup>a</sup>	64.33 ± 4.59 <sup>a</sup>
Eggshell color	23 wk	29.18 ± 5.09	31.20 ± 2.98 <sup>a</sup>
	30 wk	27.99 ± 3.95	28.92 ± 4.98 <sup>b</sup>
	44 wk	27.48 ± 3.67	25.48 ± 3.67 <sup>b</sup>
Eggshell thickness (mm)	23 wk	0.34 ± 0.03	0.33 ± 0.03 <sup>b</sup>
	30 wk	0.35 ± 0.02	0.34 ± 0.02 <sup>b</sup>
	44 wk	0.37 ± 0.03	0.38 ± 0.03 <sup>a</sup>
Eggshell weight (g)	23 wk	6.94 ± 0.94 <sup>b</sup>	6.70 ± 0.83 <sup>c</sup>
	30 wk	7.24 ± 0.66 <sup>b</sup>	7.56 ± 0.63 <sup>b</sup>
	44 wk	9.15 ± 0.49 <sup>a</sup>	8.87 ± 0.90 <sup>a</sup>
Eggshell strength (kg/cm <sup>2</sup> )	23 wk	4.01 ± 0.89 <sup>b</sup>	3.51 ± 0.88 <sup>c</sup>
	30 wk	4.82 ± 1.06 <sup>a</sup>	4.24 ± 0.99 <sup>b</sup>
	44 wk	5.17 ± 0.78 <sup>a</sup>	5.03 ± 0.91 <sup>a</sup>
Yolk color	23 wk	7.26 ± 1.21 <sup>c</sup>	7.60 ± 0.86 <sup>b</sup>
	30 wk	8.17 ± 0.90 <sup>b</sup>	7.79 ± 0.89 <sup>b</sup>
	44 wk	10.75 ± 0.43 <sup>a</sup>	10.75 ± 0.62 <sup>a</sup>
Albumen height (mm)	23 wk	7.48 ± 1.66 <sup>b</sup>	7.43 ± 1.28 <sup>b</sup>
	30 wk	6.81 ± 1.55 <sup>b</sup>	<b>7.87 ± 1.37<sup>a</sup></b>
	44 wk	8.08 ± 0.87 <sup>a</sup>	8.24 ± 1.06 <sup>a</sup>
Haugh unit (HU)	23 wk	87.40 ± 9.80	87.21 ± 7.96 <sup>b</sup>
	30 wk	83.19 ± 11.03	88.71 ± 8.71 <sup>b</sup>
	44 wk	88.75 ± 5.03	89.52 ± 5.70 <sup>a</sup>

# 다단식 산란계 사육시설 (Multi-tier)

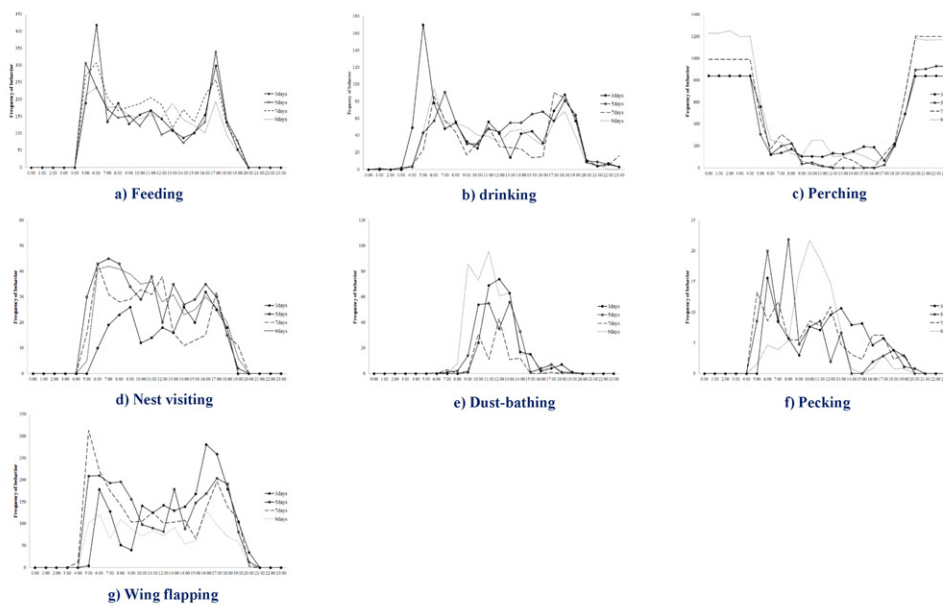


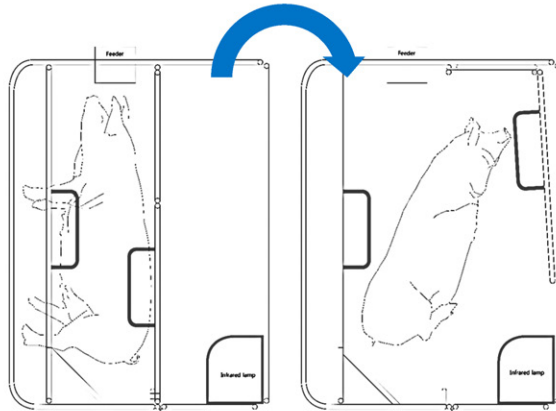
Fig. 1. Timing of behavioral changes in laying hens during the observation period.

## 분만틀 대체 사육시설 (Alternative Farrowing Pen)

### 분만틀 대체 사육시설

- 동물복지 인증기준 충족 (5일 이후 자유롭게 움직일 수 있음)
- 개체관리를 위한 보정 가능
- 발정재귀일 평균 1일 단축

농가보급 현황(26) : 273개



- ✓ 기존 분만틀 사육시설 활용 가능
- ✓ 추가적인 면적이 필요 없음
- ✓ 국내 사육여건을 반영하여 연구·개발

## 분만틀 대체 사육시설 (Alternative Farrowing Pen)

Table 3. Effects of the AFP on the performance (mean ± SD) of sows and litters

Variable	Type of farrowing pen		P-value
	Farrowing pen	Alternative farrowing pen	
<b>Sow</b>			
No. of sows	32	32	
Parity	4.5 ± 2.53	4.4 ± 2.5	> 0.05
Feed intake, kg/d	6.39 ± 0.47	6.39 ± 0.86	> 0.05
Backfat thickness, mm			
Before farrowing	15.7 ± 4.5	16.5 ± 4.7	> 0.05
At weaning	14.2 ± 3.9	14.1 ± 4.3	> 0.05
Backfat thickness loss	-2.1 ± 3.1	-2.5 ± 3.8	> 0.05
Weaning to estrus interval	5.1 ± 1.0 <sup>a</sup>	4.3 ± 0.5 <sup>b</sup>	0.0008
<b>Piglet</b>			
Litter size, Piglets/litter			
At d 1 postpartum <sup>1)</sup>	10.1 ± 1.2	9.8 ± 0.9	> 0.05
At weaning	9.0 ± 1.2	8.8 ± 1.5	> 0.05
Avg. birth weight, kg	1.5 ± 0.3	1.6 ± 0.3	> 0.05
Avg. weaning weight, kg	7.6 ± 1.2	8.1 ± 1.3	> 0.05

## 분만틀 대체 사육시설 (Alternative Farrowing Pen)

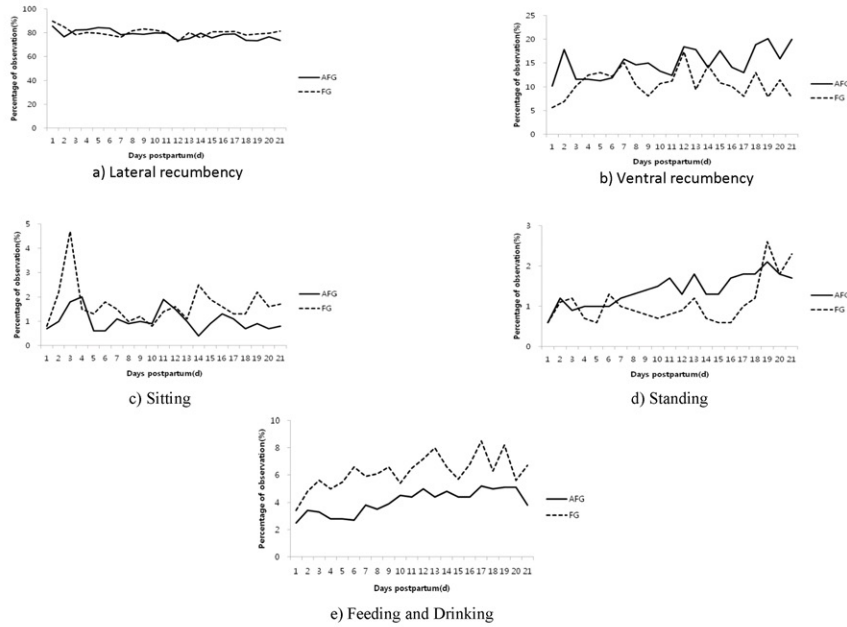


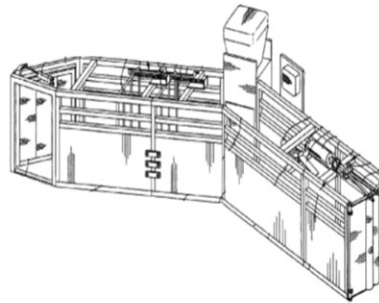
Fig. 2. Percentage of the sows' behaviors during the lactating period.

## 임신돈 군사장치 (Electronic Sow Feeder)

### 임신돈 군사장치

- 동물복지 인증기준 충족 (수정 후 4주 ~ 분만 전 1주 사용)
- 1일 3~4회 급이(사료허실 약 12% 감소)
- 재발정률 5% 이하(스톨 10~20%)

농가보급 현황(26) : 26대



- ✔ 해외 유사시설 가격인하 유도 (설치비용 : 3,000만원/대 → 1,600만원/대)
- ✔ 국내 사육여건을 반영하여 연구·개발

# 임신돈 군사사육(ESF)

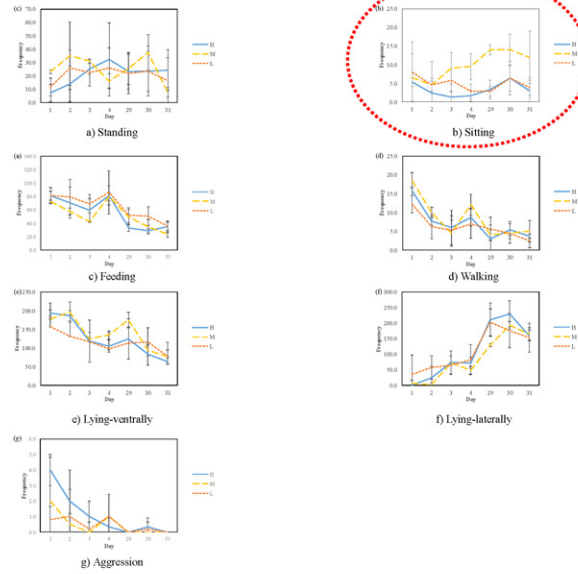


Fig. 3. Daily changes in behavior frequencies by social rank in group-housed sows.

# 한우 발정탐지



Fig. 4. Data collection for estrus behavior of cows.

Table 4. Mean values ( $\pm$  S.D.) of activity and mounting behavior during the peri-estrus period

Parameter*	Day						p-value
	-3	-2	-1	0	1	2	
Activity, m							
24-h periods	114.4 $\pm$ 155.5b	353.8 $\pm$ 173.3ab	608.2 $\pm$ 199.7a	684.9 $\pm$ 264.4a	597.6 $\pm$ 248.4a	536.0 $\pm$ 189.5a	<0.001
6-h periods	28.6 $\pm$ 38.9b	88.5 $\pm$ 46.3ab	152.0 $\pm$ 53.4a	171.2 $\pm$ 70.7a	149.4 $\pm$ 66.4a	134.0 $\pm$ 50.7a	<0.001
2-h periods	9.5 $\pm$ 13.0c	29.5 $\pm$ 15.4bc	50.7 $\pm$ 17.8a	57.1 $\pm$ 23.6a	49.8 $\pm$ 22.1a	44.7 $\pm$ 16.9ab	<0.0001
Mounting, no.							
24-h periods	11.0 $\pm$ 17.7	35.8 $\pm$ 40.7	31.3 $\pm$ 25.6	47.9 $\pm$ 34.2	21.5 $\pm$ 19.5	36.8 $\pm$ 21.7	0.22
6-h periods	2.8 $\pm$ 4.4b	8.9 $\pm$ 10.2ab	7.8 $\pm$ 6.3ab	12.0 $\pm$ 8.6a	5.4 $\pm$ 4.9ab	9.2 $\pm$ 5.4ab	<0.05
2-h periods	0.9 $\pm$ 1.5c	3.0 $\pm$ 3.4ab	2.6 $\pm$ 2.1ab	4.0 $\pm$ 2.9a	1.8 $\pm$ 1.6ab	3.1 $\pm$ 1.8ab	<0.01

발정기간 생체정보(활동량, 승가행위) 측정 및 데이터 변환

생체정보를 2시간 간격으로 데이터셋화하여 정리하는 것이 가장 효과적이라 판단

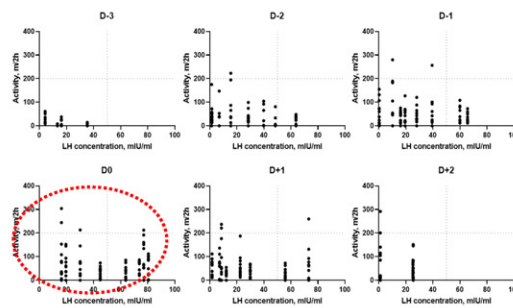


Fig. 5. The relationships between activity and LH concentration.

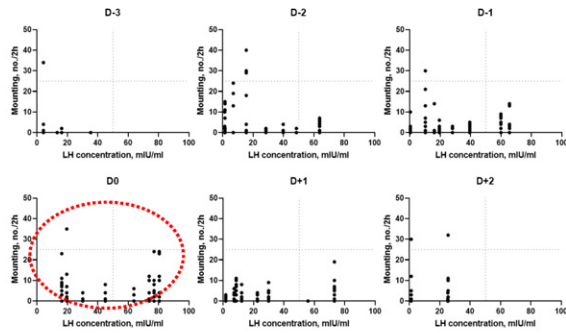


Fig. 6. The relationships between mounting behavior and LH concentration.

```

=====
XGBoost parameter: {'learning_rate': 0.01, 'max_depth': 10, 'min_child_weight': 1, 'n_estimators': 300}
XGBoost predict accuracy rate: 0.9292
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LightGBM parameter: {'learning_rate': 0.1, 'max_depth': 25, 'n_estimators': 100, 'num_leaves': 100}
LightGBM predict accuracy rate: 0.9292
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CatBoost parameter: {'border_count': 254, 'depth': 5, 'iterations': 250, 'l2_leaf_reg': 5, 'learning_rate': 0.1}
CatBoost predict accuracy rate: 0.9470 *
=====
LogisticRegression parameter: {'C': 1.0, 'max_iter': 200}
LogisticRegression predict accuracy rate: 0.8664
=====
    
```

## Rat의 가스 실신



## Rat의 가스 실신

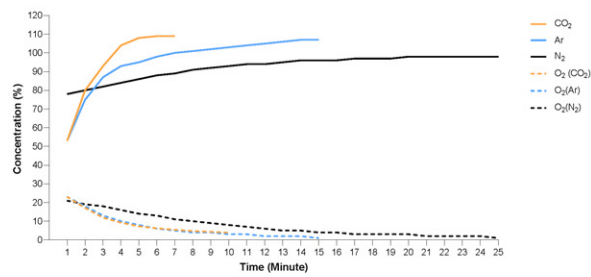


Fig. 6. Average concentrations of oxygen and gas in the chamber during the experiments.

호흡을 제외한 모든 움직임이 멈추는 것으로 정의되는 운동 소실(LOM)은 의식 상실의 조기 지표  
LOM에 도달하는 평균 시간은 CO2그룹에서 6분 45초, Ar그룹에서 11분 45초, N2그룹에서 17분 15초

## Rat의 가스 실신

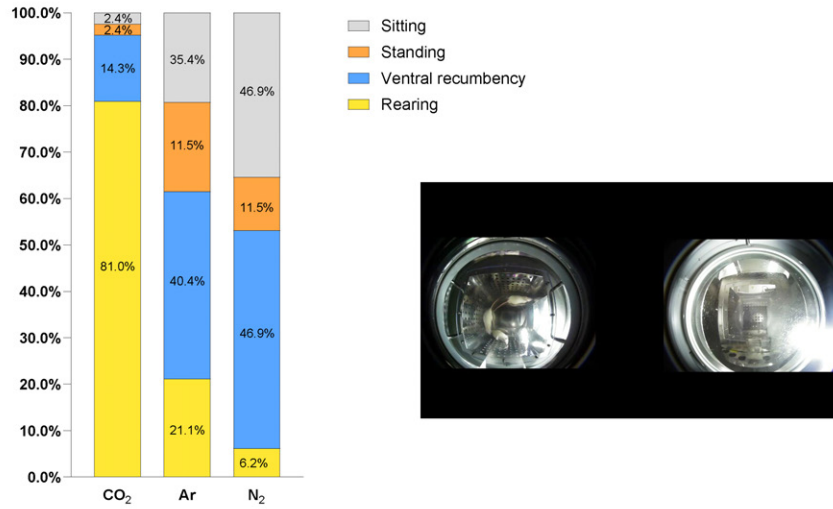


Fig. 7. Proportion of four behaviors (sitting, standing, ventral recumbency, and rearing) observed during gas exposure in each treatment group (CO<sub>2</sub>, N<sub>2</sub> and Ar).

## Rat의 가스 실신

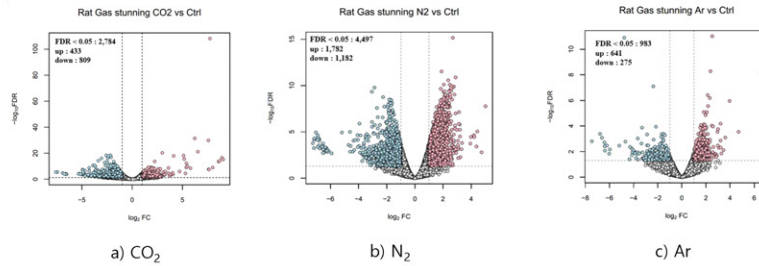
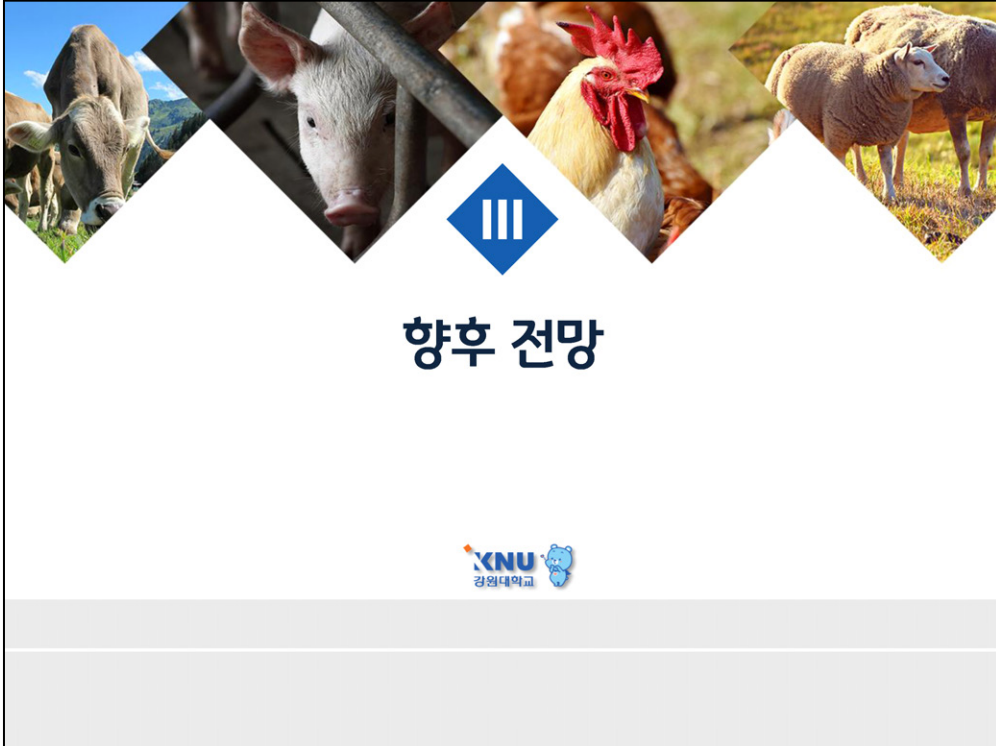


Fig. 8. Transcriptional profiling in whole blood samples against CO<sub>2</sub>, N<sub>2</sub>, Ar gas

Volcano plot 이용 차등적 유전자 1,242개(CO<sub>2</sub>), 2,962개(N<sub>2</sub>), 916개(Ar) 확인

CO<sub>2</sub> 는 면역 및 염증, N<sub>2</sub> 는 헌탄탕 질병 관련한 기능성 유전자 변화 관찰

Ar은 염증 활성화 없이 완만한 변화



## 향후 전망



### 학술적 변화



- ◆ (가축관리) 동물의 행동과 디지털 기술과의 접목을 통한 번식 효율 증대, 질병 예방
  - AI 기반 각 개체별 행동 특성을 고려한 실시간 분석  
(발정 감지, 분만 예측 등)
  - 행동학적 사전 징후에 기반한 질병 조기 탐지
- ◆ (복지평가) 시설, 환경 변화에 대한 동물의 반응을 이용한 동물복지 수준 평가
  - 사회적 서열 및 스트레스에 대한 역학적 평가  
(자동 급이기, 체중 선별기 등 시설에 대한 스트레스 지수 평가)
  - 다차원적 평가 지표의 통합
- ◆ (Nudge) 동물의 고유한 행동 습성을 활용한 효율적 관리
  - 가축의 본능적 행동 이용한 효과적인 가축 이동  
(곡선 유도로, 조명 등)
  - 환경 풍부화물을 이용한 스트레스 저감

### ◆ (One Welfare) 인간, 동물, 환경은 서로 긴밀하게 연결

- 다학제적 접근  
(동물행동학, 동물복지학, 영양학, 시설환경학, 사회복지학, 심리학 등)
- 동물복지라는 것에 대한 학술적 증명
- 소비자 신뢰  
(동물행동학, 동물복지학, 영양학, 시설환경학, 사회복지학, 심리학 등)
- 정책 수립

# 감사합니다





# The Role of Vitamin D in the Antioxidant Status of Pigs

장 영 달

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## Curriculum Vitae

- ▶ 2023~현재 미국 조지아대학교 조교수
- ▶ 2017~2023 미국 위스콘신 대학교 - River Falls 조교수
- ▶ 2012~2017 미국 켄터키 대학교 박사후 연구원
- ▶ 2005~2012 서울대학교 농생명공학부 단위동물영양생화학실 박사
- ▶ 2001~2005 서울대학교 동물자원과학과 학사





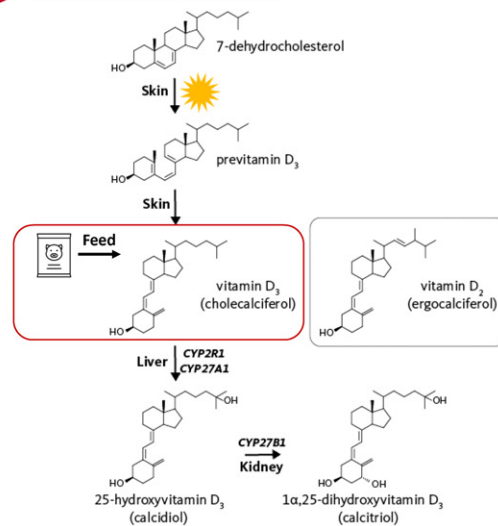
# The Role of Vitamin D in the Antioxidant Status of Pigs

Young Dal Jang and Chan Ho Kwon

*Department of Animal and Dairy Science, University of Georgia, Athens,  
GA*



## Chemical Structures of Vitamin D



One of the fat-soluble vitamins / Secosteroid hormones

Synthesized in skin via UV-B exposure / Ingested through diet

Vitamin D<sub>3</sub> (cholecalciferol): animal-derived or UV-synthesized

Vitamin D<sub>2</sub> (ergocalciferol): plant/fungal-derived

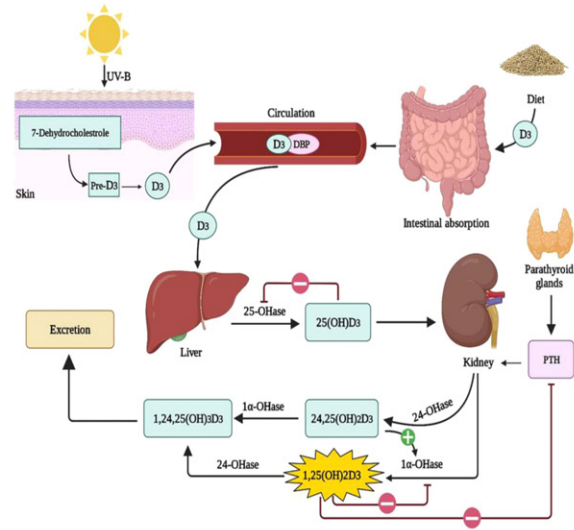
## Vitamin D in the body

### Intestinal Absorption

- Micelle formation
- Packaged into chylomicrons
- Transported in blood (vitamin D binding protein)

### Activation

- Two-step hydroxylation in liver and kidney
- Liver: Vitamin D  $\rightarrow$  25-OHD<sub>3</sub>
- Kidney: 25-OHD<sub>3</sub>  $\rightarrow$  1,25(OH)<sub>2</sub>D<sub>3</sub>



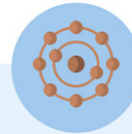
## Function of Vitamin D in animal body



- Intestinal Ca/P absorption
- Osteoblast activity  $\rightarrow$  bone mineralization

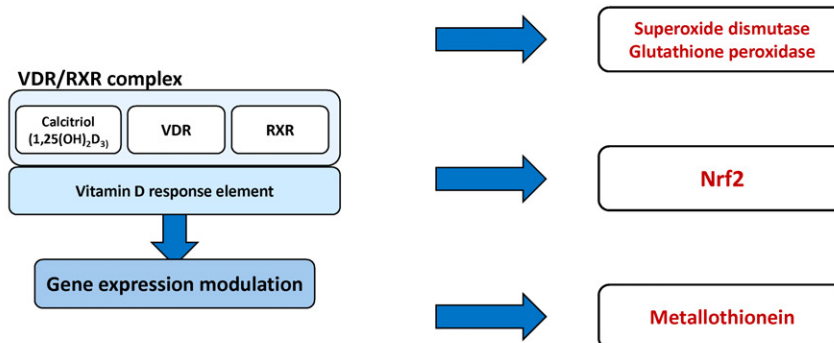


- $\downarrow$  Pro-inflammatory cytokines
- $\uparrow$  Antimicrobial peptides



- $\uparrow$  Antioxidant enzyme expressions
- $\downarrow$  Oxidative stress marker

## Antioxidant potential of Vitamin D



## Antioxidant potential of Vitamin D

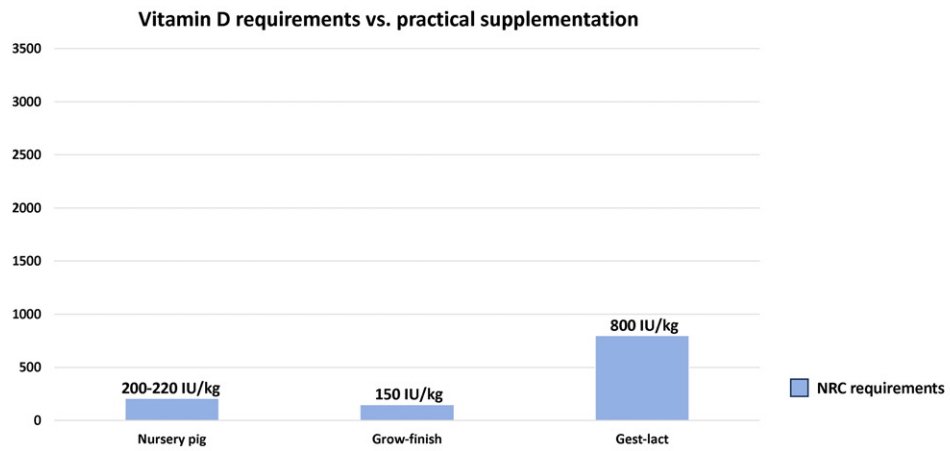
- Superoxide dismutase**  
**Glutathione peroxidase**
  - Remove ROS directly
  - Decrease lipid peroxidation
- Nrf2**
  - Binds antioxidant response element
  - Promoting antioxidant system
- Metallothionein**
  - Vitamin D receptor directly binds on metallothionein gene receptor
  - Directly neutralizes hydroxyl radicals



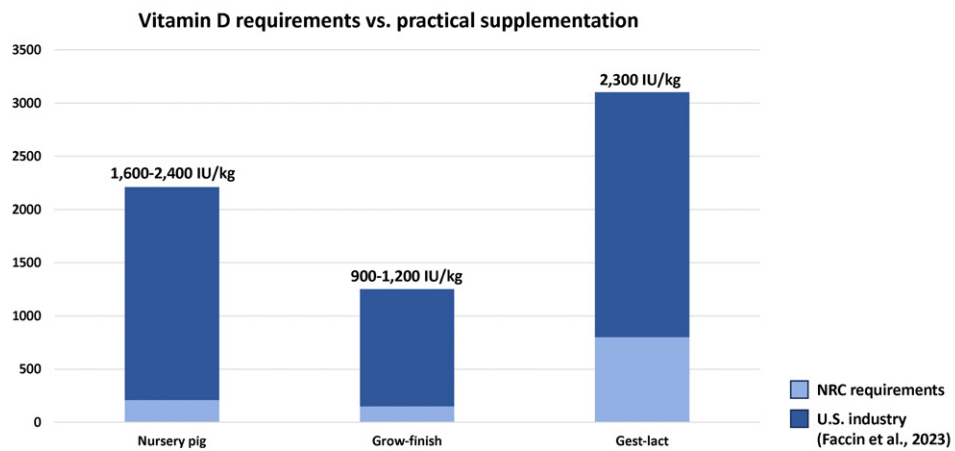
### Improve antioxidant status

- ↑ Glutathione
- ↑ Glutathione peroxidase
- ↑ Superoxide dismutase
- ↑ Total antioxidant capacity
- ↓ Reactive oxygen species
- ↓ Malondialdehyde

## The use of Vitamin D in swine diets



## The use of Vitamin D in swine diets



## Objectives

To evaluate the effects of dietary  $VD_3$  supplementation on blood **vitamin D status** and **antioxidant capacity** in weaning pigs.

## Vitamin D in nursery pigs

### Study 1

- 40 newly weaned pigs (6.02 kg; 17.2 d of age)
- 5 replicates with 4 pigs per pen
- Treatments:
  1. **NRC- $VD_3$** : 220 (Phase 1) and 200 (Phase 2) IU/kg of  $VD_3$
  2. **High- $VD_3$** : 2,000 IU/kg of  $VD_3$  for both Phase 1 and Phase 2

### Open Access

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<https://doi.org/10.5713/ab.25.0525>  
pISSN 2765-0189 eISSN 2765-0235



### Effects of dietary vitamin $D_3$ supplementation on growth performance, blood vitamin D status, and antioxidant capacity in weaning pigs

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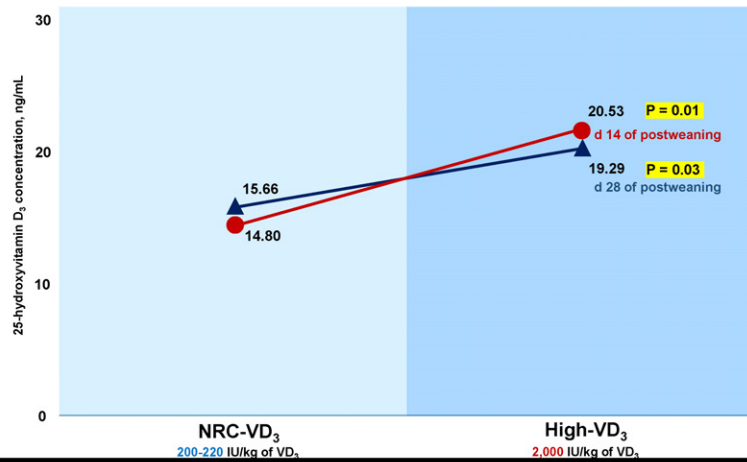
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Submitted Jul 23, 2025; Revised Sep 23, 2025;  
Accepted Oct 6, 2025

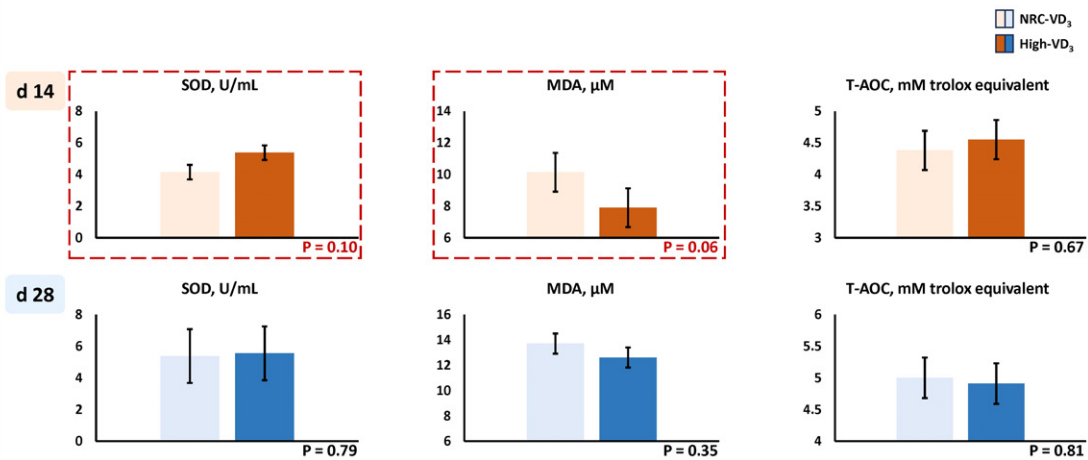
**Objective:** This study evaluated the effects of dietary vitamin  $D_3$  ( $VD_3$ ) supplementation on growth performance, blood vitamin D, and antioxidant status in weaning pigs.  
**Methods:** Forty newly weaned piglets (6.02±1.17 kg) were assigned to two treatments with five replicates over a 28-d period. Treatments were 1) NRC- $VD_3$ ; NRC recommended levels (220 IU/kg in Phase 1 [d 0–14 postweaning] and 200 IU/kg in Phase 2 [d 14–28 postweaning]), and 2) High- $VD_3$ ; a high level of  $VD_3$  (2,000 IU/kg in Phase 1 and 2). Body weight, average daily gain, average daily feed intake, and gain-to-feed ratio were measured weekly. Blood samples were collected at d 14 and 28 postweaning for the analyses of plasma 25-hydroxycholecalciferol (25-OHD), total antioxidant capacity (T-AOC), superoxide dismutase (SOD) activity, and malondialdehyde (MDA) levels. Pearson correlation coefficients between plasma 25-OHD, and SOD, MDA, or T-AOC were determined.  
**Results:** Growth performance did not differ in overall nursery period although feed intake was lower in the High- $VD_3$  group than the NRC- $VD_3$  group in d 14–28 postweaning ( $p<0.05$ ). Pigs fed High- $VD_3$  diets showed greater plasma 25-OHD, at d 14 and 28 postweaning ( $p<0.05$ ), tended to have reduced plasma MDA ( $p=0.06$ ), and increased plasma SOD activity ( $p=0.10$ ) at d 14 postweaning compared with those fed NRC- $VD_3$  diets with no effect in plasma T-AOC. At d 14 postweaning, plasma 25-OHD, was positively correlated with plasma SOD activity ( $r=0.532$ ;  $p<0.05$ ) and tended to be negatively correlated with plasma MDA levels ( $r=-0.491$ ;  $p=0.06$ ).  
**Conclusion:** High  $VD_3$  supplementation at 2,000 IU/kg did not enhance growth performance, while improving plasma vitamin D and antioxidant status in weaning pigs compared to NRC-level supplementation. Therefore, supplementing weaning pigs with higher-than-recommended levels of  $VD_3$  could be beneficial to enhance their antioxidant status and overall health.

**Keywords:** Antioxidant Status; Growth Performance; Oxidative Stress; Vitamin  $D_3$ ; Weaning Pig

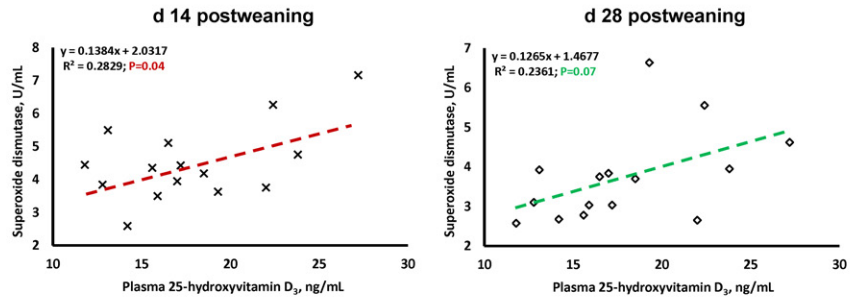
## High-VD<sub>3</sub> increased plasma 25-OHD<sub>3</sub> levels



## High-VD<sub>3</sub> increased SOD activity and decreased MDA levels

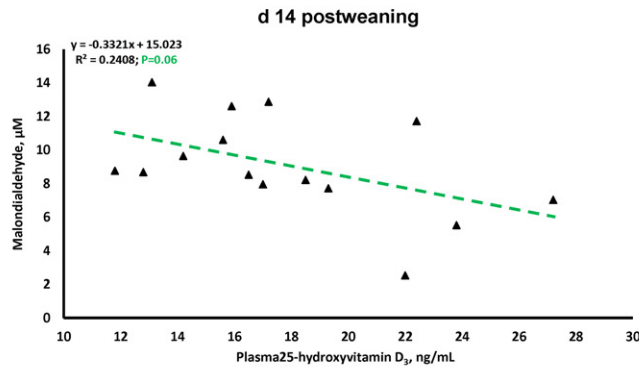


## SOD activity is **positively correlated** with vitamin D status



Plasma 25-OHD<sub>3</sub> levels are **correlated** with SOD activity in nursery pigs

## MDA level is **negatively correlated** with vitamin D status



Plasma 25-OHD<sub>3</sub> levels are **negatively correlated** with MDA concentrations

## Vitamin D<sub>3</sub>

- NRC levels vs. 2,000 IU/kg VD<sub>3</sub> supplementation
  - ↑ Plasma 25-OHD<sub>3</sub> levels
  - ↑ Antioxidant status & ↓ oxidative stress
- Recommend exceeding VD<sub>3</sub> supplementation over NRC requirements for health benefits

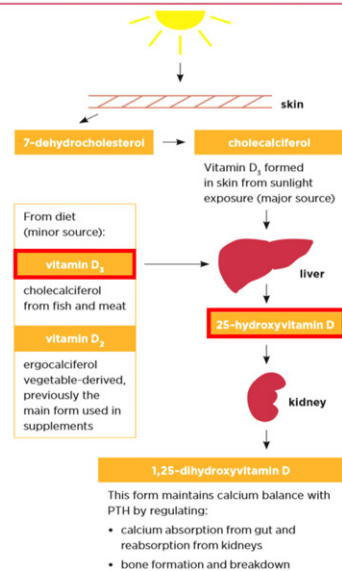
Plasma 25-OHD<sub>3</sub> levels were correlated with SOD activity and MDA levels

What if we could elevate plasma 25-OHD<sub>3</sub> levels further?

## 25-OHD<sub>3</sub>

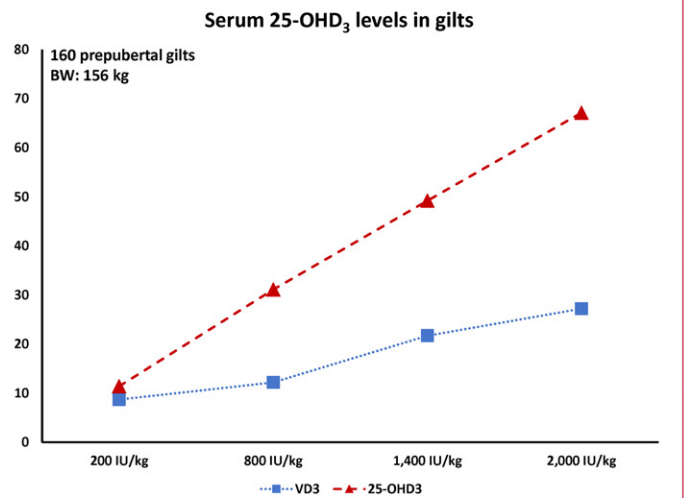
### Metabolized form of VD<sub>3</sub>

- Major circulating form of Vitamin D
- Hydroxylated in the liver after absorption
- Bypass the metabolic process of VD<sub>3</sub> in liver



## VD<sub>3</sub> vs. 25-OHD<sub>3</sub>

25-OHD<sub>3</sub> supplementation can further increase blood 25-OHD<sub>3</sub> levels compared with VD<sub>3</sub>



(Burild et al., 2016)

## Objectives

To evaluate the effects of dietary 25-OHD<sub>3</sub> on blood vitamin D status and antioxidant capacity in weaned pigs

# 25-OHD<sub>3</sub> in nursery pigs

## Study 2

- 48 newly weaned pigs (5.27 kg; 18.7 d of age)
- 4 replicates with 4 pigs per pen
- Treatments:
  - VD<sub>3</sub> 2,000 IU/kg
  - 25-OHD<sub>3</sub> 1,000 IU/kg
  - 25-OHD<sub>3</sub> 2,000 IU/kg

## Study 3

- 60 newly weaned pigs (5.63 kg; 17.9 d of age)
- 5 replicates with 4 pigs per pen
- Treatments:
  - VD<sub>3</sub> 2,000 IU/kg
  - VD<sub>3</sub> 1,000 IU/kg + 25-OHD<sub>3</sub> 1,000 IU/kg
  - 25-OHD<sub>3</sub> 2,000 IU/kg

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pISSN 2765-0189 eISSN 2765-0235



Effects of dietary 25-hydroxycholecalciferol supplementation on growth performance, blood vitamin D and antioxidant status in nursery pigs

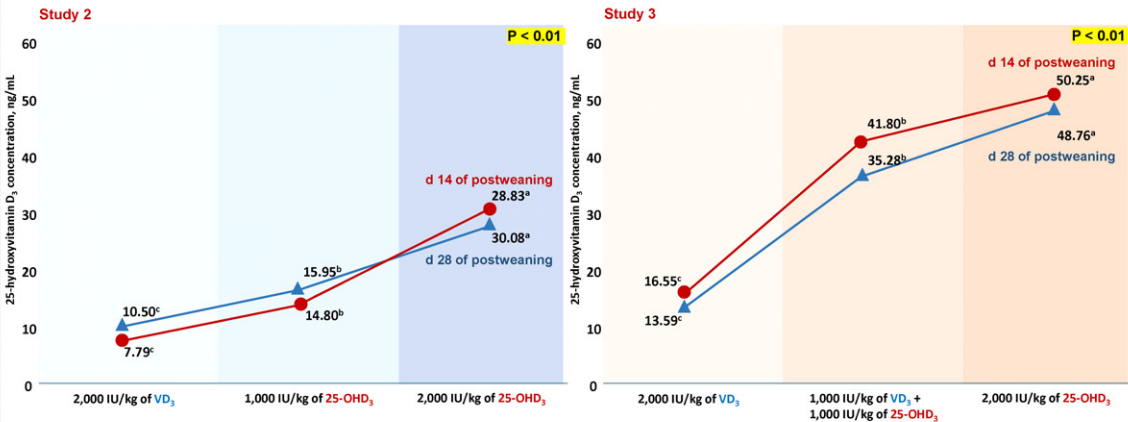
Chan Ho Kwon<sup>1</sup>, Eva S. Safaie<sup>1</sup>, Savannah L. Locke<sup>1</sup>, Jannell A. Torres<sup>1</sup>, Zhaohui Yang<sup>2</sup>, Xi Chen<sup>1</sup>, and Young Dal Jang<sup>1\*</sup>

Article

Effects of Dietary 25-Hydroxycholecalciferol Alone or in Combination with Vitamin D<sub>3</sub> on Growth Performance, Blood Vitamin D Status, Immune Response, Bone Integrity, and Antioxidant Capacity of Nursery Pigs

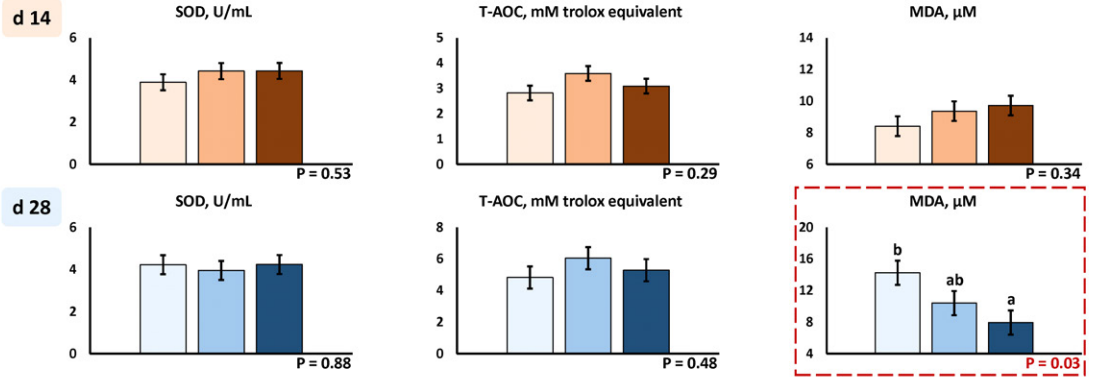
Chan Ho Kwon<sup>1</sup>, Eva S. Safaie<sup>1</sup>, Jannell A. Torres<sup>1</sup>, Zhaohui Yang<sup>2</sup>, Xi Chen<sup>1</sup>, Pengcheng Xue<sup>2</sup> and Young Dal Jang<sup>1\*</sup>

# 25-OHD<sub>3</sub>



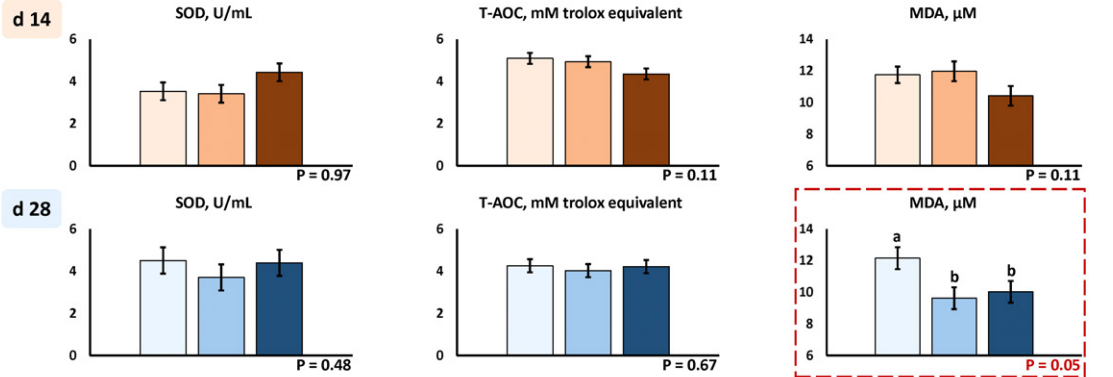
# 25-OHD<sub>3</sub>

## Antioxidant status (study 2)



# 25-OHD<sub>3</sub>

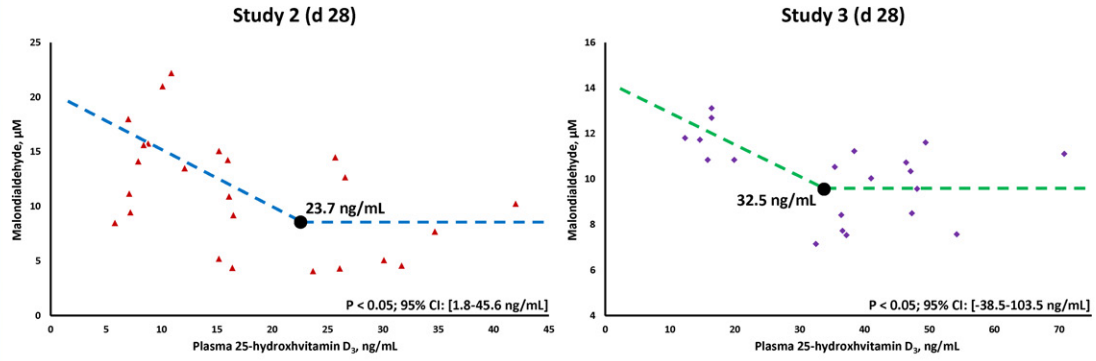
## Antioxidant status (study 3)



# 25-OHD<sub>3</sub>

The plasma MDA level was minimized when plasma 25-OHD<sub>3</sub> levels reached 23.7 (study 1) and 32.5 (study 2) ng/mL at d 28 postweaning

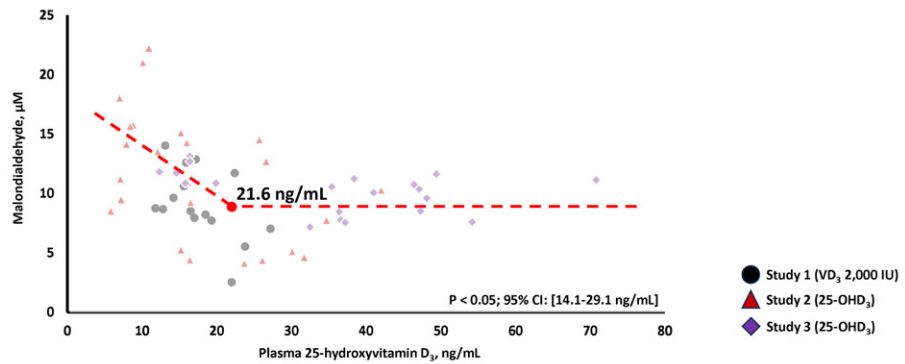
## Broken-line analysis



# Overall

Based on our studies, we concluded that 21.6 ng/mL is the minimum plasma 25-OHD<sub>3</sub> level to minimize MDA concentrations

## Broken-line analysis



## 25-OHD<sub>3</sub>

- 25-OHD<sub>3</sub> supplementation vs. VD<sub>3</sub> supplementation
  - ↑ Plasma 25-OHD<sub>3</sub> levels
  - ↑ Antioxidant status and ↓ oxidative stress
- Increase in plasma 25-OHD<sub>3</sub> levels by 25-OHD<sub>3</sub> supplementation further reduce oxidative stress

Plasma 25-OHD<sub>3</sub> levels were correlated with MDA levels

What about 25-OHD<sub>3</sub> supplementation in sow diets?

## Objectives

To evaluate the effects of **dietary 25-OHD<sub>3</sub> supplementation during late gestation and lactation** on vitamin D status, milk composition, antioxidant capacity, and immune responses in sows and their progeny during the suckling period.

## 25-OHD<sub>3</sub> in sow diets

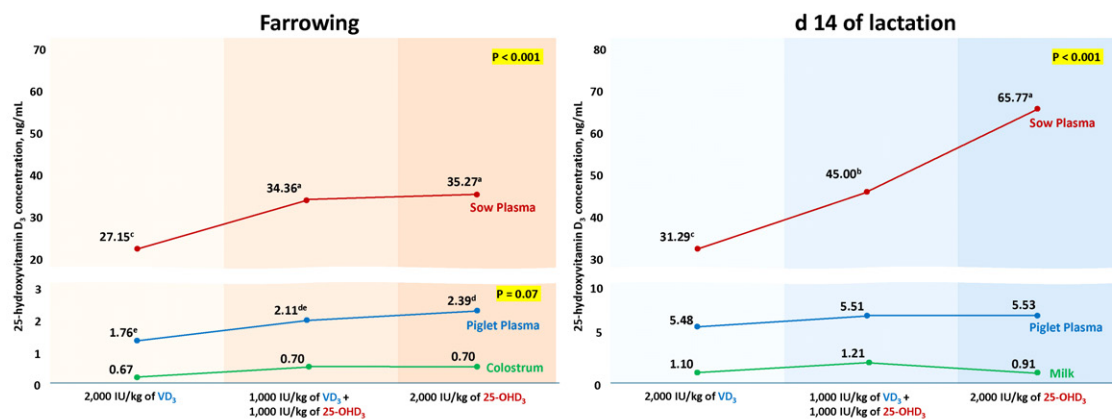
### Study 4

- 30 sows in d 105-108 of gestation
- 3 treatments with 10 replicates each
- Same diets were fed in late gestation and lactation periods
- Blood and milk samples were collected
- Treatments:
  - VD<sub>3</sub> 2,000 IU/kg
  - VD<sub>3</sub> 2,000 IU/kg + 25-OHD<sub>3</sub> 1,000 IU/kg
  - 25-OHD<sub>3</sub> 2,000 IU/kg

### Sample analysis

- Vitamin D status (plasma and milk)
- Milk compositions
- Antioxidant parameters (plasma and milk)
  - Superoxide dismutase
  - Total antioxidant capacity
  - Malondialdehyde
- Immunoglobulin G (plasma and milk)

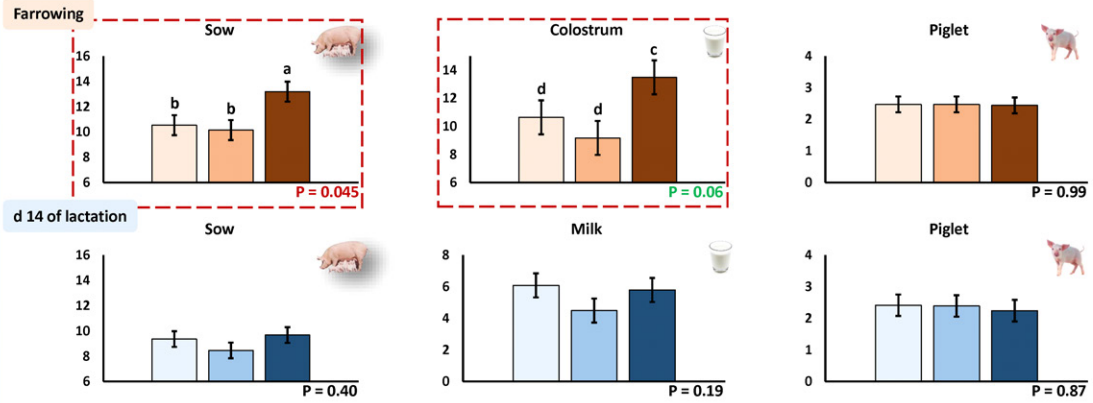
## 25-OHD<sub>3</sub> in sow diets



## 25-OHD<sub>3</sub> in sow diets

Superoxide dismutase, U/mL

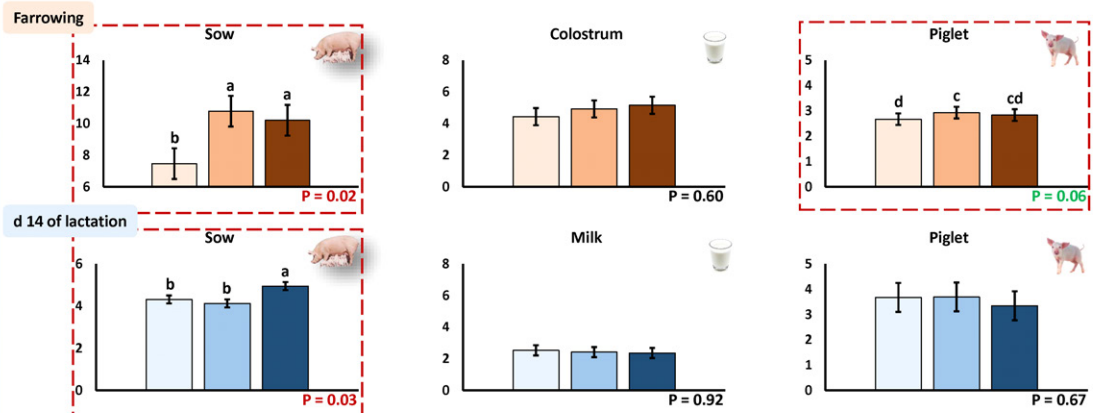
VD<sub>3</sub> 2,000 IU/kg  
 VD<sub>3</sub> + 25-OHD<sub>3</sub>  
 25-OHD<sub>3</sub> 2,000 IU/kg



## 25-OHD<sub>3</sub> in sow diets

Total antioxidant capacity, mM Trolox equivalents

VD<sub>3</sub> 2,000 IU/kg  
 VD<sub>3</sub> + 25-OHD<sub>3</sub>  
 25-OHD<sub>3</sub> 2,000 IU/kg

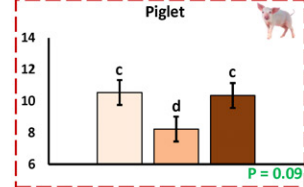
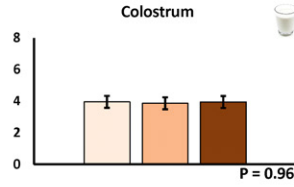
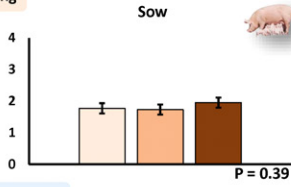


# 25-OHD<sub>3</sub> in sow diets

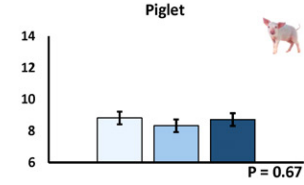
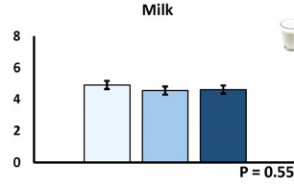
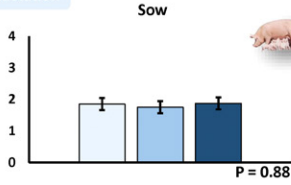
Malondialdehyde,  $\mu\text{M}$

■ VD<sub>3</sub> 2,000 IU/kg  
■ VD<sub>3</sub> + 25-OHD<sub>3</sub>  
■ 25-OHD<sub>3</sub> 2,000 IU/kg

Farrowing



d 14 of lactation

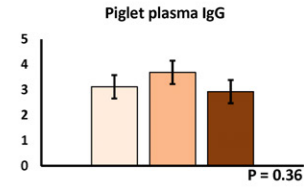
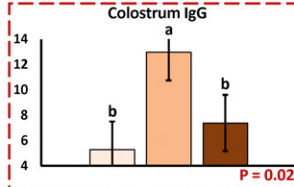
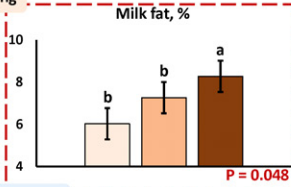


# 25-OHD<sub>3</sub> in sow diets

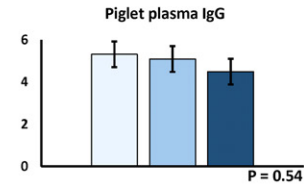
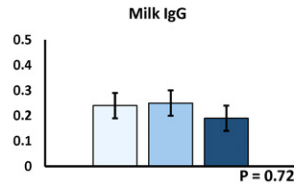
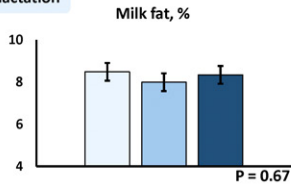
Milk fat & IgG levels, mg/mL

■ VD<sub>3</sub> 2,000 IU/kg  
■ VD<sub>3</sub> + 25-OHD<sub>3</sub>  
■ 25-OHD<sub>3</sub> 2,000 IU/kg

Farrowing



d 14 of lactation



## 25-OHD<sub>3</sub> in sow diets

- 25-OHD<sub>3</sub> supplementation vs. VD<sub>3</sub> supplementation in sow diets
  - ↑ Plasma 25-OHD<sub>3</sub> levels in sows and their progeny
  - ↑ Antioxidant status in sows
  - ↓ Oxidative stress in piglets
  - ↑ Colostrum fat and IgG contents

25-OHD<sub>3</sub> improved the health status of sows and milk

↓

Their progeny also improved their early health

## Summary

### Nursery pig

- High-VD<sub>3</sub> supplementation: ↑ Vitamin D status ↑ Antioxidant status
- 25-OHD<sub>3</sub> supplementation: ↑ Vitamin D status ↑ Antioxidant status
- Vitamin D status and oxidative stress are negatively correlated

### Sow

- 2,000 IU/kg of 25-OHD<sub>3</sub> supplementation enhanced...
  - Vitamin D status, superoxide dismutase, total antioxidant capacity, milk fat contents, and colostrum IgG levels

### Suckling pig

- 25-OHD<sub>3</sub> supplementation in sow diets...
  - Increased vitamin D status and antioxidant capacity
  - Decreased oxidative stress

## Take home messages

High vitamin D<sub>3</sub> can increase vitamin D status and antioxidant capacity, while **25-OHD<sub>3</sub>** is more efficient

In nursery pigs, vitamin D requirement should be determined based on **plasma 25-OHD<sub>3</sub>** levels

The use of vitamin D<sub>3</sub> may be **insufficient** for enhanced vitamin D status compared to **25-OHD<sub>3</sub>**

## Acknowledgements



### Jang Lab

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Madison Mejia (Undergraduate student)  
Shelby Greer (Undergraduate student)

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Allen Xue (PhD)  
Xixi Chen (PhD)  
Kristy Dorton (PhD)

# Amino Acid Nutrition in Pigs and Chickens

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- ▶ 2020~2024 미국 퍼듀대학교 축산학과 농학박사
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# Amino acid nutrition in pigs and chickens

**Jung Yeol Sung**

**Pusan National University**

**July 10, 2026**

## Content



- **Introduction**
- **Exp. 1**
  - **Impact of coccidia challenge on lysine requirement in broiler chickens**
- **Exp. 2**
  - **Nutritional needs of non-essential amino acids in nursery pigs**
- **Conclusion**

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# Introduction



## ➤ Roles of amino acids (AA)

- **Building blocks** for protein synthesis
- **Functional AA** that **regulate key metabolic pathways** that are necessary for maintenance, growth, reproduction, and immunity

Wu, 2010 3

# Introduction



## ➤ Essential (indispensable) amino acids (EAA)

- AA which **cannot be synthesized** or **inadequately synthesized** by body to meet physiological needs
- Must be provided from diets

## ➤ Non-essential (dispensable) amino acids (NEAA)

- AA which can be **adequately synthesized** by body to meet physiological needs
- Not considered in typical diet formulation

Wu, 2010 4

# Introduction



- **AA requirement (expressed as % in diet)**
  - **May change in response to immune challenges**
    - **Reduced feed intake**
    - **AA need for maintenance + AA need for production**



Litvak et al., 2013; Rakhshandeh et al., 2014; Wellington et al., 2018; Jespersen et al., 2024 5

# Introduction



- **Low-protein diet**
  - **Partial replacement of SBM with supplemental AA**
  - **However, excessive reduction in dietary protein may induce NEAA deficiency**
    - **Catabolism of EAA for NEAA production**
    - **Compromised growth and intestinal health considering the functional roles of NEAA**

Heger et al., 1998; Kim et al., 2007; Wu, 2010 6

# Introduction



## ➤ Hypotheses

- **Coccidia challenge** increases lysine requirement of broiler chickens
- **NEAA deficiency** impairs intestinal health & growth when nursery pigs are fed a SBM-free diet
- **Increasing NEAA supplementation** in SBM-free diets gradually restores intestinal health & growth of nursery pigs

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# Introduction



## ➤ Objectives

- Investigate the impact of coccidia challenge on lysine requirement of broiler chickens
- Investigate the impact of graded concentrations of NEAA in SBM-free diets on intestinal health & growth of nursery pigs

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## Exp. 1: Materials and methods



- **490 birds on from d 8 to 16 post-hatch**
- **Randomized complete block design**
- **5 (lysine) × 2 (challenge) factorial**
  - **SID lysine: 0.85, 1.00, 1.15, 1.30, and 1.45%**
  - **Challenge: Saline or *Eimeria* gavage on d 9**

125,000 (*Eimeria acervulina*)

25,000 (*Eimeria maxima*)

25,000 (*Eimeria tenella*)

oocysts



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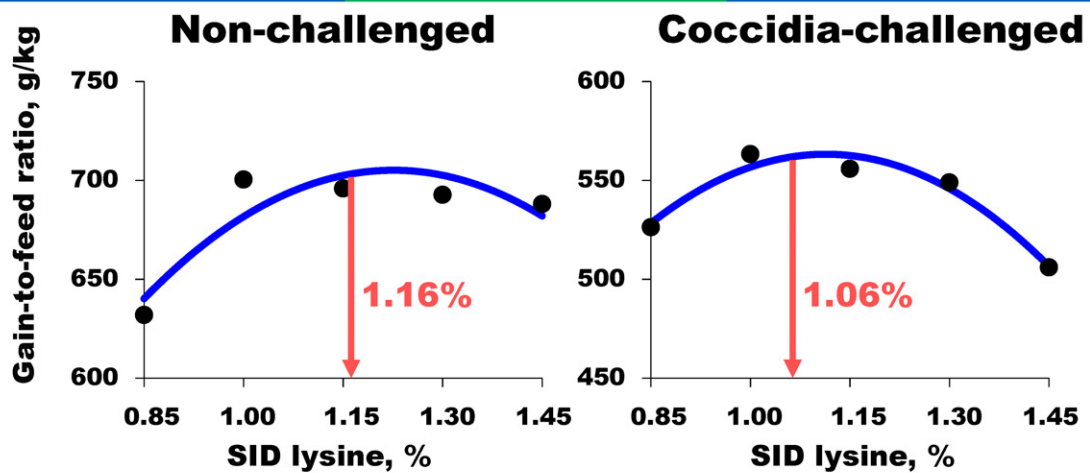
## Exp. 1: Materials and methods



	SID lysine, %				
	0.85	1.00	1.15	1.30	1.45
<b>Feedstuff, %</b>					
<b>Corn</b>	71.775	71.775	71.775	71.775	71.775
<b>Soybean meal</b>	22.000	22.000	22.000	22.000	22.000
<b>L-Lysine HCl</b>	0.155	0.345	0.535	0.725	0.915
<b>L-Glutamic acid</b>	1.210	0.910	0.610	0.310	-
<b>Cornstarch</b>	-	0.110	0.220	0.330	0.450
<b>Crude protein, %</b>	18.5	18.5	18.5	18.5	18.5
<b>SID lysine, %</b>	0.85	1.00	1.15	1.30	1.45

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## Exp. 1: Results



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## Exp. 2: Materials and methods



- **48 weaned pigs (initial BW = 6.7 kg)**
  - Randomized complete block design
  - Individually housed
  - 28 d in 3 phases (wean to 7 kg / 7 to 11 kg / from 11 kg)
- **4 diets**
  - **NC: Corn-SBM diet**
  - **PC: SBM-free diet**
  - **PC+50NEAA: PC + 50% of NEAA contribution from SBM in NC**
  - **PC+100NEAA: PC + 100% of NEAA contribution from SBM in NC**

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## Exp. 2: Materials and methods



	Phase 1 (wean to 7 kg)				Phase 2 (7 to 11 kg)				Phase 3 (from 11 kg)			
	NC	PC	PC+ 50 NEAA	PC+ 100 NEAA	NC	PC	PC+ 50 NEAA	PC+ 100 NEAA	NC	PC	PC+ 50 NEAA	PC+ 100 NEAA
<b>Feedstuff, %</b>												
<b>Corn</b>	39.33	51.78	48.92	45.63	48.74	63.37	60.08	56.30	59.18	77.21	73.15	68.49
<b>SBM</b>	19.00	-	-	-	22.00	-	-	-	27.00	-	-	-
<b>Supp. EAA</b>	0.65	3.32	3.36	3.40	0.68	3.72	3.75	3.79	0.68	4.55	4.61	4.66
<b>Supp. NEAA</b>	-	-	2.07	4.14	-	-	2.39	4.78	-	-	2.93	5.86
			↑ 50%				↑ 50%				↑ 50%	
<b>SID EAA, %</b>	9.80	8.90	8.90	8.90	8.98	7.88	7.88	7.88	8.36	7.18	7.18	7.18
<b>SID NEAA, %</b>	10.65	6.80	8.73	10.65	9.85	5.41	7.64	9.85	9.11	3.66	6.39	9.11

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## Exp. 2: Materials and methods



### ➤ Jejunum mucosa & tissue collection on d 28

- Jejunum mucosa-associated microbiota
- Jejunum tissue & mucosa
  - Gene expression  
(NOD1/2, TLR2/4, CD14, NF-κB, IFN, CLA, OCC, ZO1, mTOR, and MUC2)
  - Immune response (IL-6, IL-8, TNF-α, and IgA)
  - Oxidative damage products (protein carbonyl and MDA)
  - Morphology (villus height, crypt depth, and Ki-67<sup>+</sup> cell)

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# Exp. 2: Materials and methods

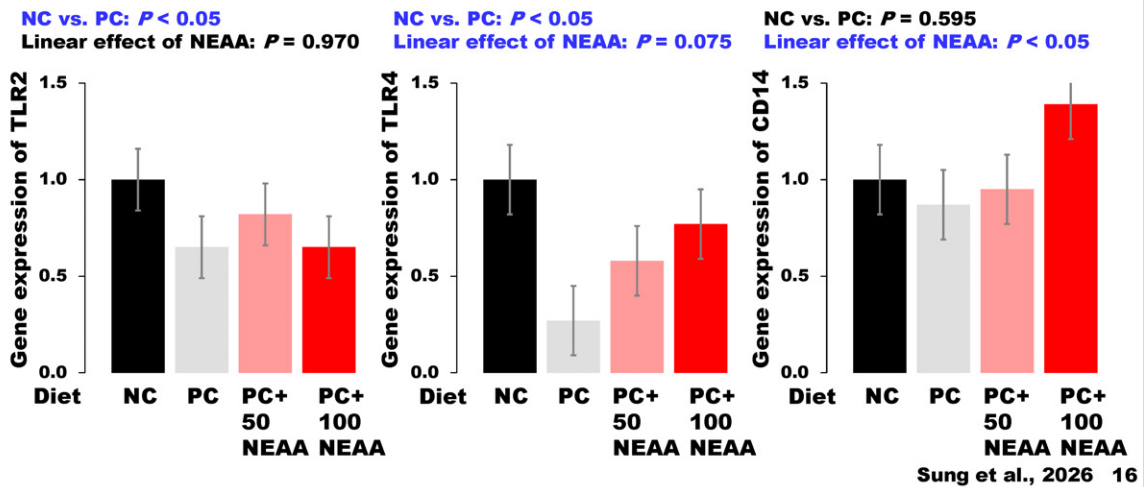


## ➤ Statistical analysis

- Growth & intestinal health data
    - Proc MIXED of SAS (fixed: diet, random: initial BW, sex)
    - Contrasts: NC vs. PC; linear effect of NEAA
  - Nutritional needs of NEAA
    - Proc NLIN of SAS (broken-line analysis)
- Significance:  $P < 0.05$ ; tendency:  $0.05 \leq P < 0.10$

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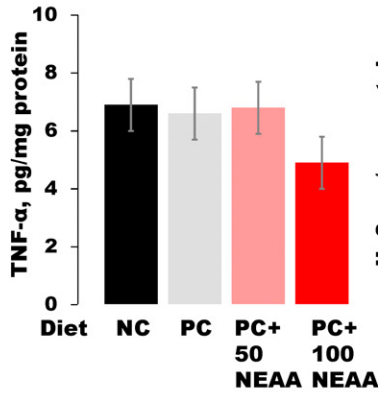
# Exp. 2: Jejunal gene expression



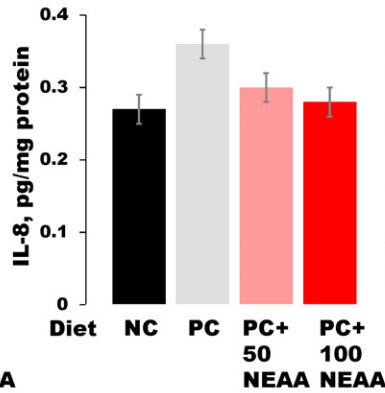
## Exp. 2: Jejunal immune responses



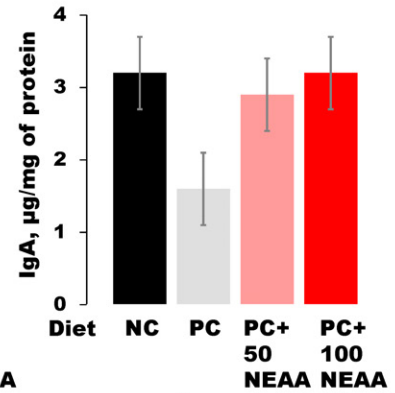
NC vs. PC:  $P = 0.820$   
Linear effect of NEAA:  $P = 0.228$



NC vs. PC:  $P < 0.05$   
Linear effect of NEAA:  $P < 0.05$



NC vs. PC:  $P < 0.05$   
Linear effect of NEAA:  $P < 0.05$

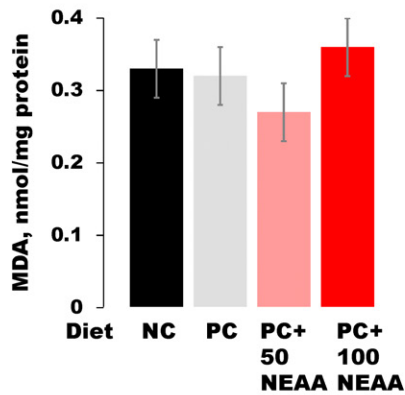


Sung et al., 2026 17

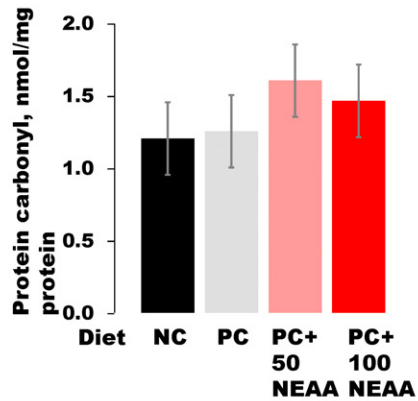
## Exp. 2: Jejunal oxidative damage



NC vs. PC:  $P = 0.856$   
Linear effect of NEAA:  $P = 0.449$

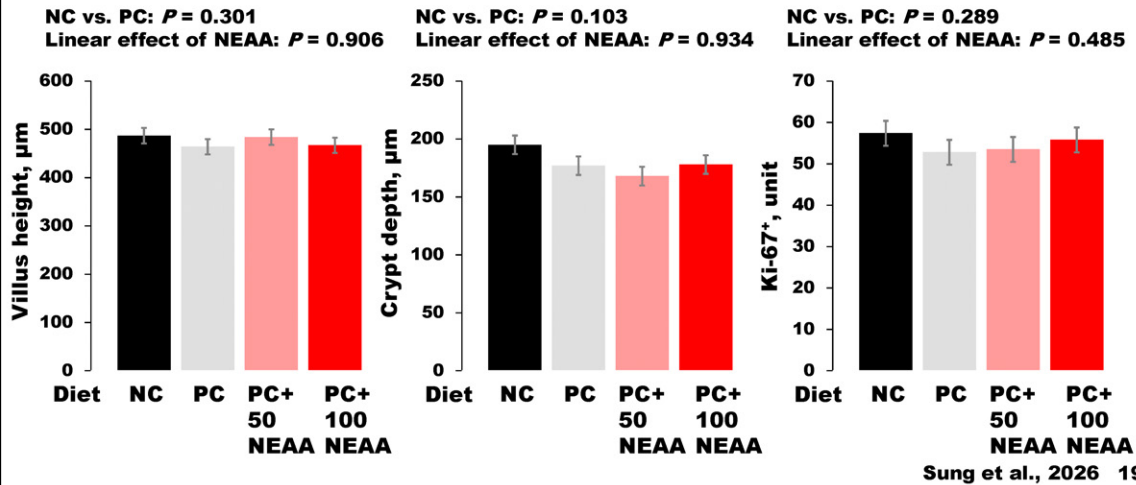


NC vs. PC:  $P = 0.904$   
Linear effect of NEAA:  $P = 0.548$

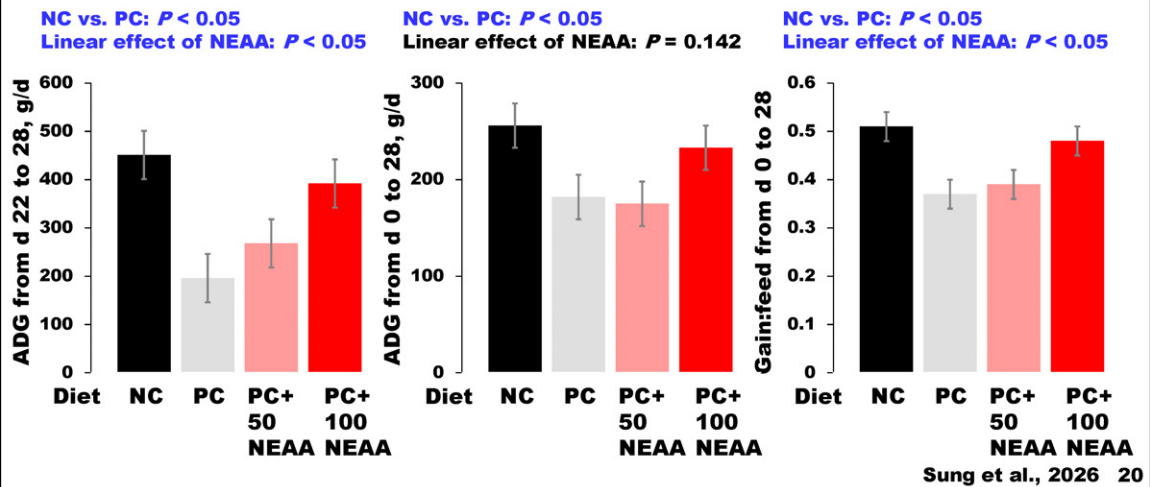


Sung et al., 2026 18

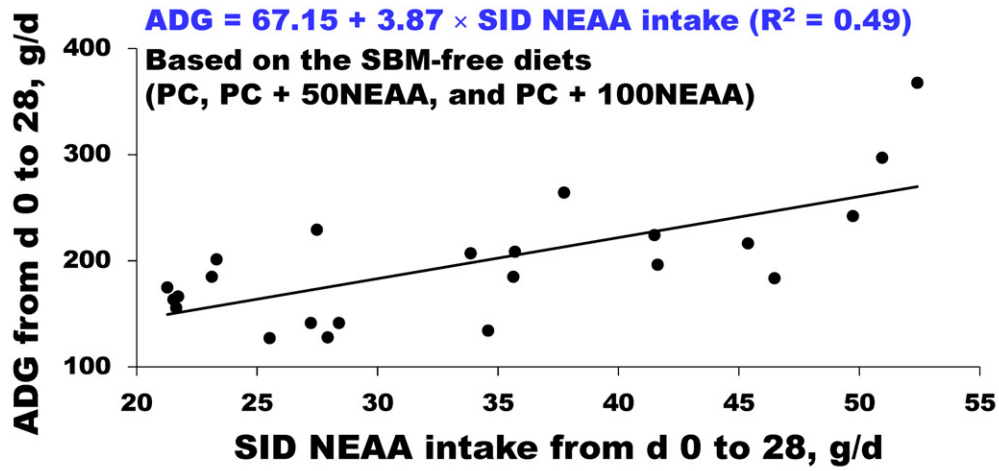
## Exp. 2: Jejunal morphology



## Exp. 2: Growth performance



## Exp. 2: Nutritional needs of NEAA



Sung et al., 2026 21

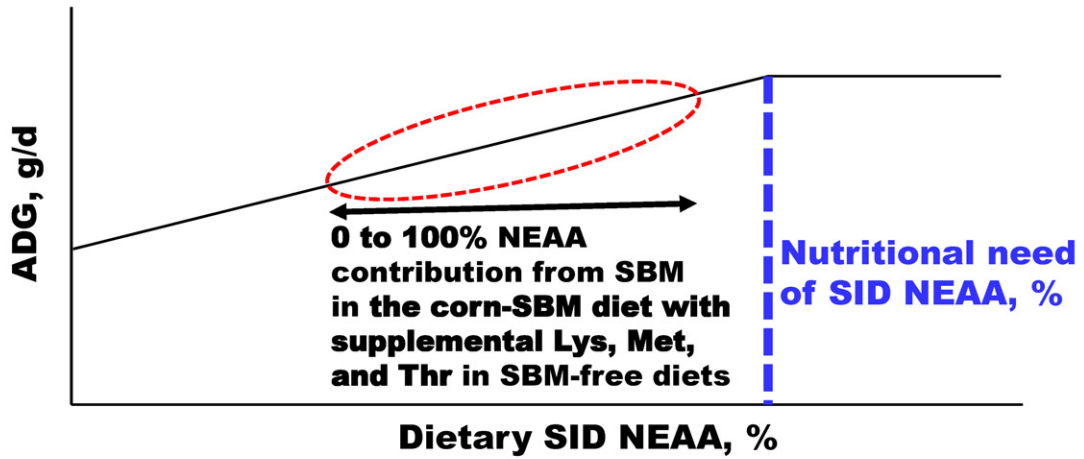
## Conclusion



- **Coccidia** may not alter Lys requirement of broilers
- The **SBM-free diet** impaired the jejunal immune responses and growth of pigs, whereas increasing NEAA mitigated the negative impacts
- **NEAA ≥ 100% contribution from SBM** in the corn-SBM diet with supplemental Lys, Met, and Thr may be necessary to optimize growth of nursery pigs fed SBM-free diets

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# Conclusion



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# Thank you



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# PRRSV Functional Genomics: Past Decade and Future Perspectives

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**Integrate EveryThing, Create Novel Thing**  
모든 것을 조합해, 새로운 것을 창조합니다.

우리는 데이터를 통해 미래를 예측합니다.  
빅데이터, 다중오믹스 분석, 인공지능 기술의 힘으로 미래를 혁신합니다.  
생명체의 비밀을 해석하고 새로운 약물과 지속 가능한 식품 생산에 이르기까지  
창의적인 사고와 윤리적인 실천으로 긍정적인 변화를 추구합니다.

# PRRSV Functional Genomics: Past Decade and Future Perspectives

Functional Genomics & Bioinformatics Lab.  
Department of Animal Science and Technology  
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**Jun-Mo Kim**



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---

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2. **Study 1** (Transcriptome in whole blood)
3. **Study 2** (Transcriptome in multiple tissues)
4. **Study 3** (Interactome between mRNAs and lncRNAs in multiple tissues)
5. **Study 4** (Single-cell transcriptome and exosomal miRNAs in BALF)
6. **Discussion**
7. **Further studies** (Epigenome and microbiome)
  - **Study 5** (Single-cell co-expression module-metabolite-microbe landscape analysis)
  - **Study 6** (PRRSV epigenomic alterations based on chromatin accessibility)



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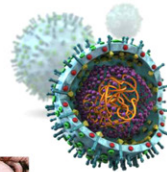
# Introduction



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## PRRSV

- Porcine reproductive and respiratory syndrome virus (**PRRSV**)
- Positive strand RNA virus, in the family *Arteriviridae*
- Two types – PRRSV1 (European), PRRSV2 (North American)
- Main target cells: monocyte / macrophage  
Porcine alveolar macrophage (PAM): ~5%

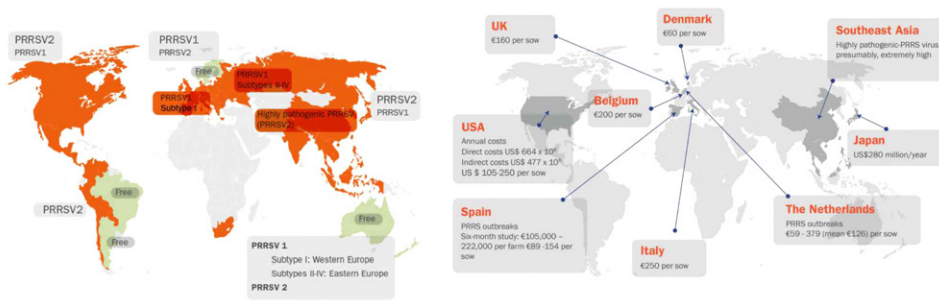


SYMPTOM	
Sows	Growing pigs
<ul style="list-style-type: none"> <li>• Abortion</li> <li>• Early farrowing</li> <li>• Stillbirth</li> <li>• Mummified piglets</li> <li>• Weak piglets</li> </ul>	<ul style="list-style-type: none"> <li>• Respiratory problems</li> </ul>



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## Economic losses by PRRSV



- PRRS is one of **the most costly disease** in pig industry
- In **Europe** and **North America**, the cost of PRRSV to the industry: \$6.25-\$15.25 USD per pig marketed (Holtkamp *et al.*, 2013; Nathues *et al.*, 2017)
- Economic losses in **Korea** (PRRSV1) (Kim *et al.*, 2022)
  - ① KRW 99,378 per mated female for the breeding-farrowing phase
  - ② KRW 8,968 per pig for the nursery growth phase
  - ③ KRW 245,174 per sow in the post-outbreak period

<https://www.prrscontrol.com/prrs-the-disease/>

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## PRRS host genetics consortium

### Participating organizations



Iowa State University



Kansas State University



Agricultural research service



National pork board

### Why was it established?



PRRSV infection shows large variation in **viral control and growth performance** among commercial pigs



PHGC was established to test whether this variation has a **genetic basis**

### Consortium approach



Standardized PRRSV challenge in commercial pig populations



**Core phenotypes:** viral load, weight gain, immune response



SNP genotype integration across experimental sites

### Expected contribution



Identify host **genetic factors** linked to PRRS resistance and resilience



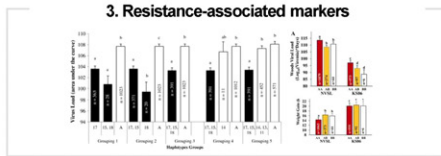
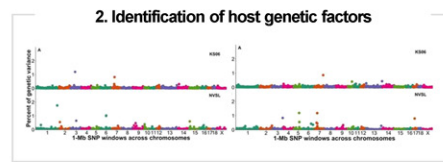
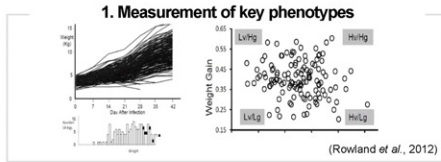
Improve understanding of host biology and **mechanisms** of protection



Provide a foundation for **mechanism-based PRRS control**

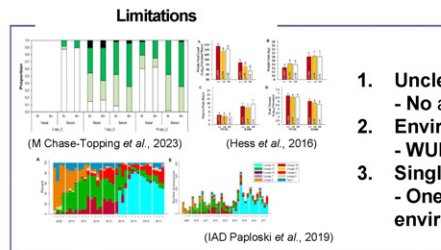
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## Host genetics approach and limitation for PRRS resistance



**Results**

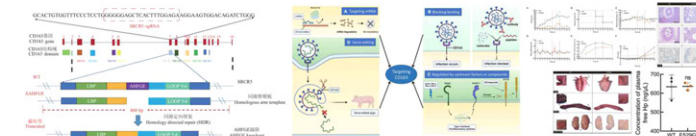
- PHGC aimed to identify host genetic factors and breed pigs with genetic resistance in lowa
- Viral load and weight gain were measured as key quantitative phenotypes after PRRSV infection
- QTL/GWAS analyses identified *Sus scrofa* chromosome 4 (SSC4)/WUR-GBP5, associated with lower viral load and partially improved weight gain



- 1. Unclear transmission control**
  - No apparent WUR effect on infectivity or susceptibility
- 2. Environment-dependent effect**
  - WUR effects on growth and viral clearance differed by strains
- 3. Single-marker limitation**
  - One marker is not robust across diverse viral environments

## Genome Editing Approaches : Strategy, and Limitation

### Target receptor and editing strategy



- PRRSV entry depends on **CD163**, making receptor editing a direct intervention strategy
- **E529G** reduced serum viral load under PRRSV challenge while preserving **CD163** related physiological function

### Limitation of GE-based PRRS resistance

**Partial Protection Only**

- JXA1 challenge: viral load  $\sim 2 \log_{10}$ , WT 2/3 died vs E529G 3/3 survived
- But fever/symptoms present  $\rightarrow$  partial protection, not sterilizing (Pan et al., 2024)

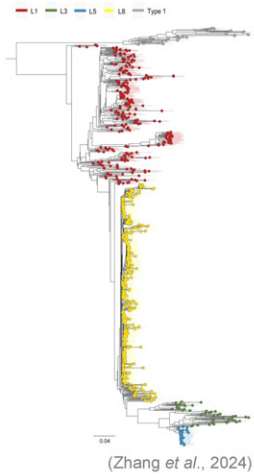
**Long-term observation required**

- CD163 = M2 marker, Hb-Hp scavenger, HO-1 anti-inflammatory multifunctional receptor
- Short-term function preserved; long-term/multi-animal/multi-environment unverified (Thomsen et al., 2013)

**Lack of single-strain verification**

- PRRSV-2: 9 lineages, frequent recombination, shifting dominant strains
- Tested only against single strain JXA1  $\rightarrow$  escape/cross-lineage defense unevaluated (Zhang et al., 2024)

## PRRS Research Shift: Host-Virus Interaction



### Viral variation as an environmental factor of mechanistic change

- **Viral variation** is a major challenge in PRRSV control as an **environmental factor**
- **Evolving PRRSV** may alter viral entry, pathogenicity, and **disease outcomes**
- **Marker-based approaches** are **insufficient** to overcome **viral diversity**

### Host-virus interaction as a sustainable framework

- Mechanisms may vary, but the **interaction-based perspective** provides a **sustainable framework**
- This perspective **shifts interpretation** from marker association to **biological mechanisms**

**A model** comprehensively **capturing host-virus interactions** is necessary

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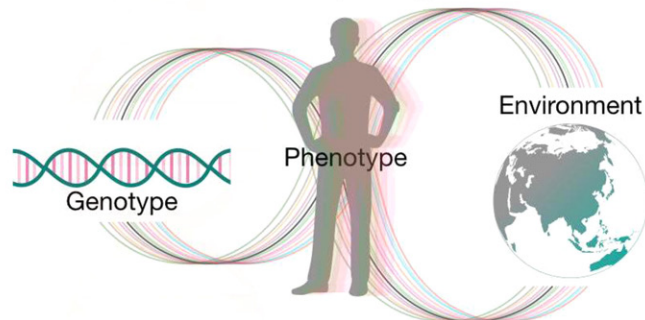
## Animal Model for Phenotype Evaluation

$$P = G + E$$

\* P : Phenotypic Value. G : Genotypic Value. E : Environmental Deviation

$$G * E$$

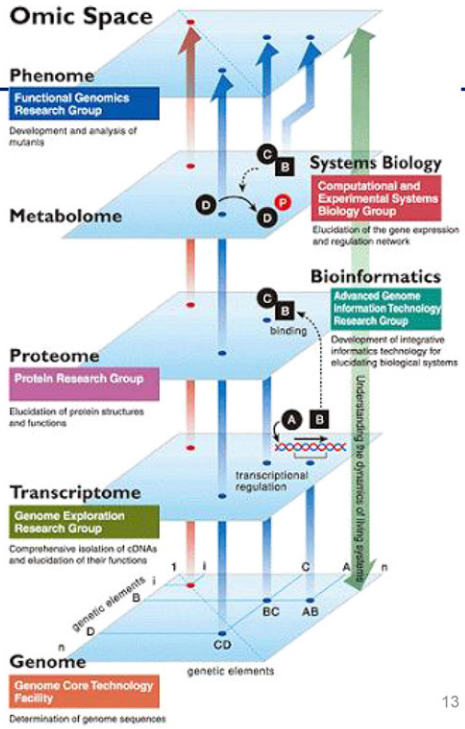
- G effected by E
- It cause the transformations of the phenotype



geneticeducation.co.in

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# Functional Genomics 'MOI'



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# Multi-Omics Integration 'MOI'

Scientific Reports, 2018  
Animal Genetics, 2018 & 2019  
Functional Integrative & Genomics, 2019  
Veterinary Research, 2020

Absolute fold change (FC)  $\geq 4$   
Absolute correlation coefficient  $\geq 0.9$

630 nodes  
7565 edges

• Node color: Tissue and day

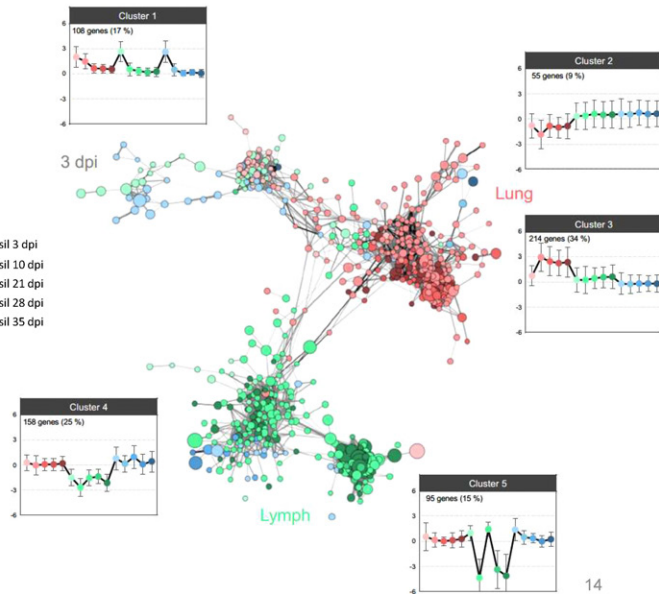
- |               |                |                 |
|---------------|----------------|-----------------|
| ○ Lung 3 dpi  | ○ Lymph 3 dpi  | ○ Tonsil 3 dpi  |
| ○ Lung 10 dpi | ○ Lymph 10 dpi | ○ Tonsil 10 dpi |
| ○ Lung 21 dpi | ○ Lymph 21 dpi | ○ Tonsil 21 dpi |
| ○ Lung 28 dpi | ○ Lymph 28 dpi | ○ Tonsil 28 dpi |
| ○ Lung 35 dpi | ○ Lymph 35 dpi | ○ Tonsil 35 dpi |

• Node size: Total max value

• Edge color: Up down

— Up      — Down

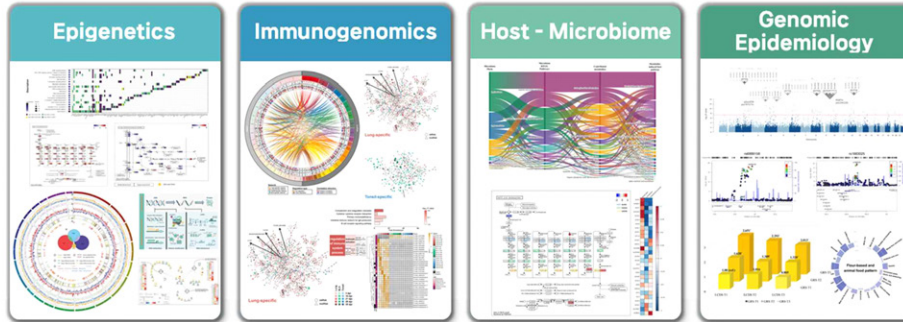
• Edge width: Correlation coefficient value



14

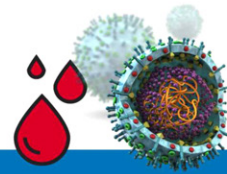
## Multi-Omics Data Integration

빅데이터 기반 멀티오믹스 분석으로 생명현상에 대한 **통합적 이해**를 제공합니다.



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### Study 1



**Integrative time-serial network based on cell deconvolution of whole blood transcriptome unveils systemic antiviral activities and cell-specific immunological changes against PRRSV infection**

*Veterinary Research, 2025*



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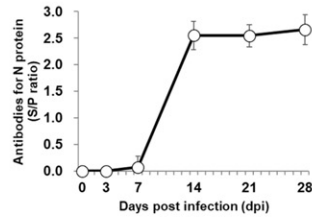
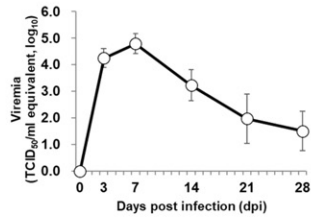
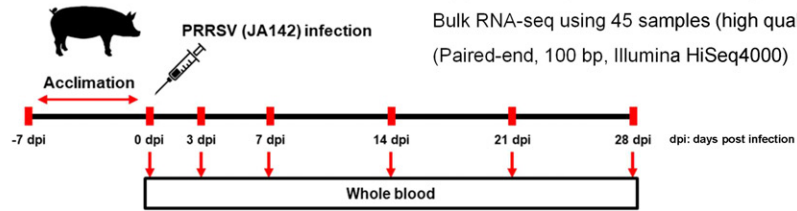
# 1 Experiment design & phenotypes

4-week-old piglets ( $n = 8$ )

Landrace ( $\delta$ )  $\times$  Yorkshire ( $\text{♀}$ )  $\times$  Duroc ( $\delta$ )

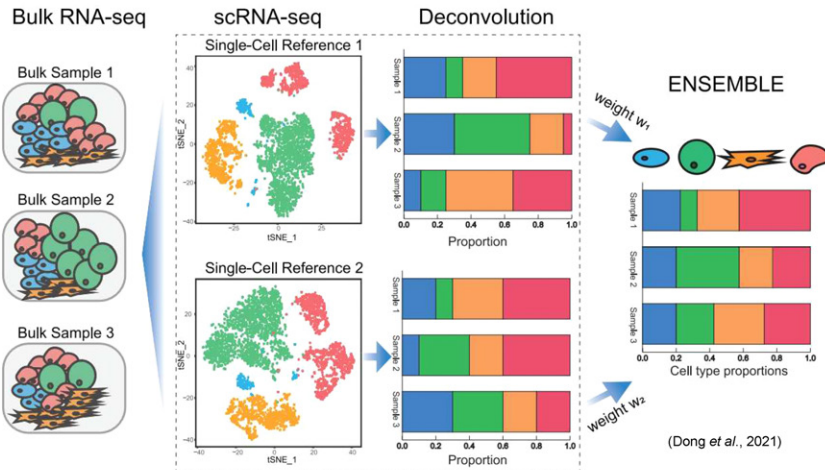
8 pigs  $\times$  6 time points = **total 48 samples**

Bulk RNA-seq using 45 samples (high quality)  
(Paired-end, 100 bp, Illumina HiSeq4000)



17

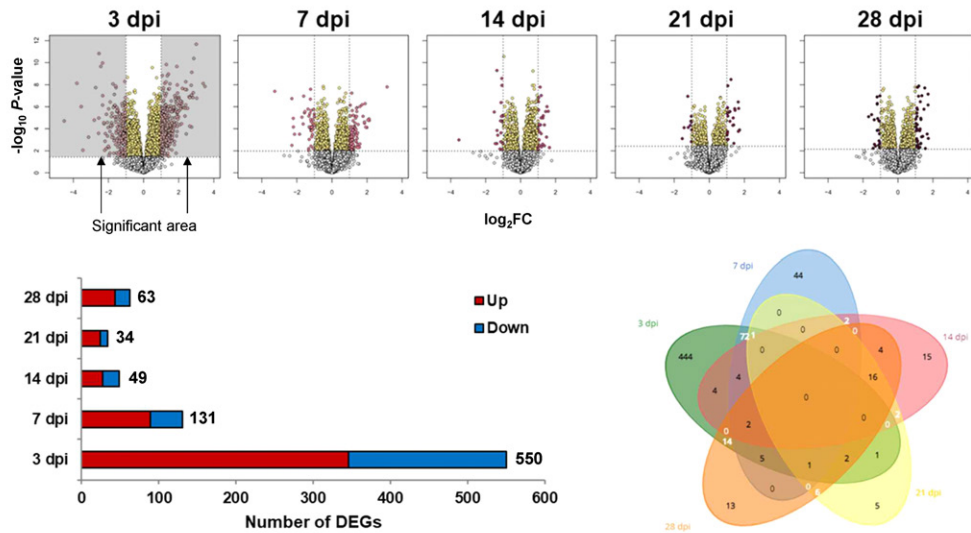
# 1 Cell deconvolution



To estimate cell proportions in bulk whole blood samples

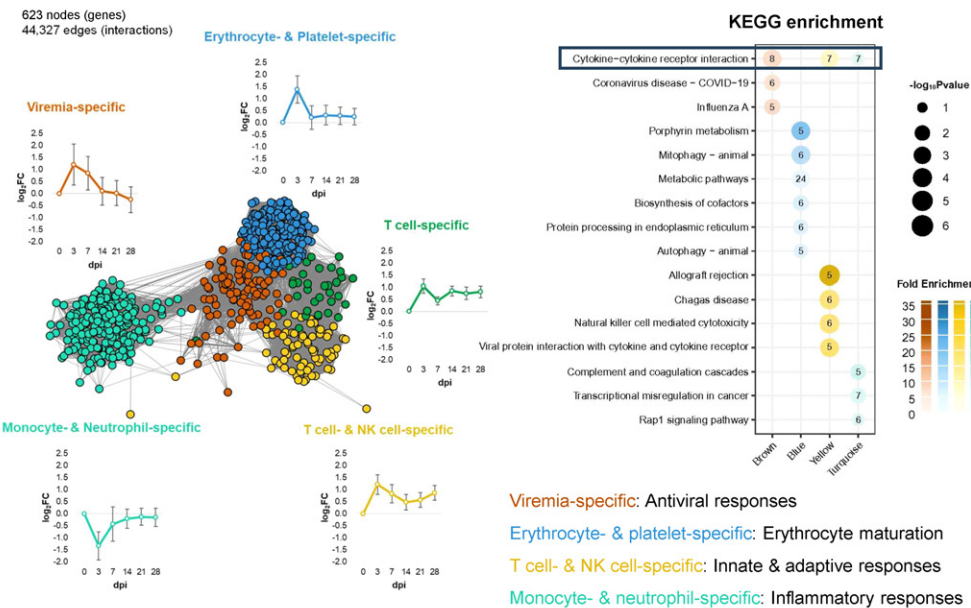
18

## 2 DEG profiling



19

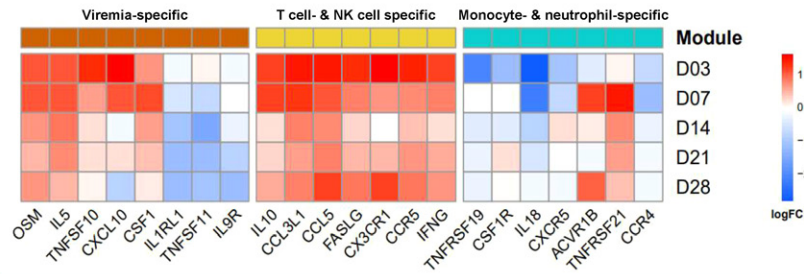
## 3 Gene co-expression network



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## 4 Gene modulation

### Cytokine-cytokine receptor interaction



- **OSM** (activated T cells, monocytes, and macrophages), **IL5** (activated T cells), **TNFSF10** (activated T cells, NK cells, and macrophages), **CXCL10** (activated T cells, neutrophils, and monocytes), and **CSF1** (monocytes)
- STAT3 (**OSM** and **IL5**) and STAT5 (**IL5** and **CSF1**) in **JAK/STAT signaling** are crucial factor for differentiation of Th<sub>17</sub> and T<sub>reg</sub>, contributing adaptive immune responses
- **CSF1** (activation of phagocyte system), **TNFSF10** (apoptosis), and **CXCL10** (chemoattraction of monocytes and T cells)

- **IL10** (anti-inflammatory), **IFNG** (pro-inflammatory), and **CCL5** (chemoattraction) are **mainly expressed in activated T cells**, contributing adaptive immune responses

- **IL18** is marker for antigen presenting cells, and it **stimulates both innate and adaptive immune responses**

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## Conclusions

- **Antiviral activities** by various immune cells and **T cell differentiation** through JAK/STAT signaling pathway at early times after PRRSV infection are up-regulated
- **T cell populations** are increased through chemoattraction regulation
- **Innate and adaptive immune signaling** through mainly activated **T cells** are up-regulated at early times and maintained at late times after the infection
- **Circulating monocytes and neutrophils** migrate to local target organs such as the lung, indicating down-regulation of inflammatory responses in blood

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## Study 2



# Integrated time-serial transcriptome networks reveal common innate and tissue-specific adaptive immune responses to PRRSV infection

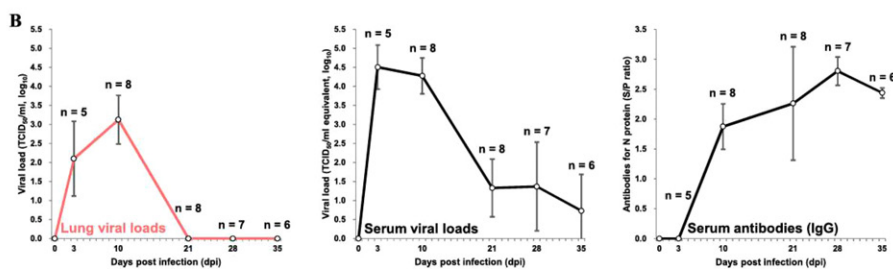
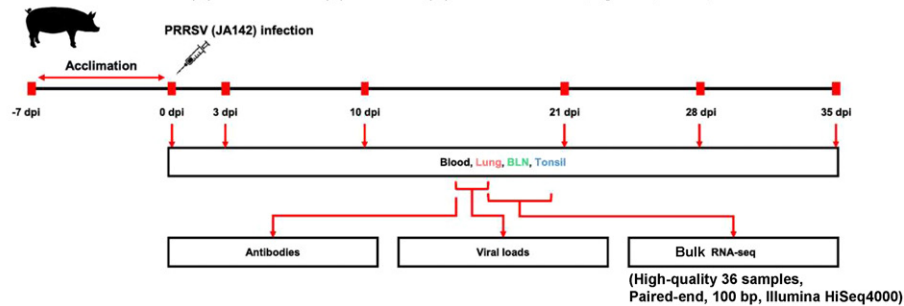
Veterinary Research, 2020



23

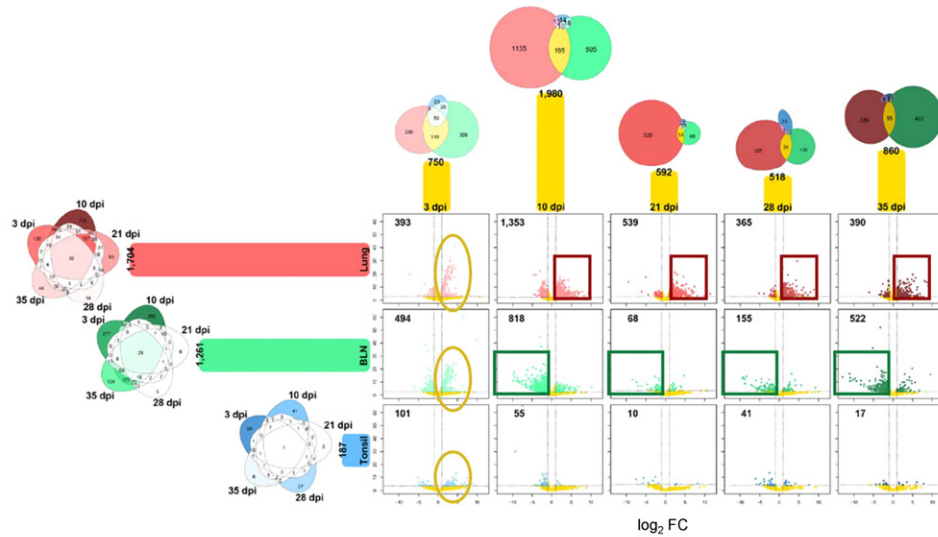
## 1 Experiment design & phenotypes

A Landrace (♂) × Yorkshire (♀) × Duroc (♂) 4-week-old piglets (n = 40)



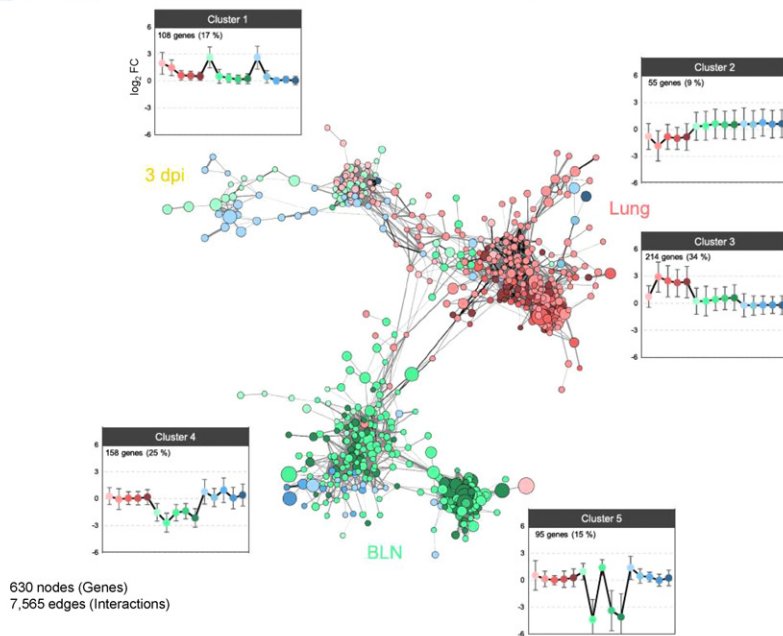
24

## 2 DEG profiling



25

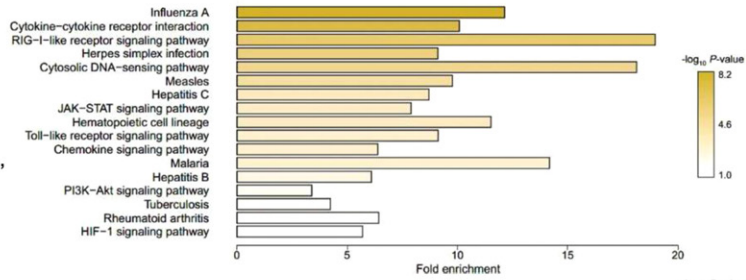
## 3 Gene co-expression network



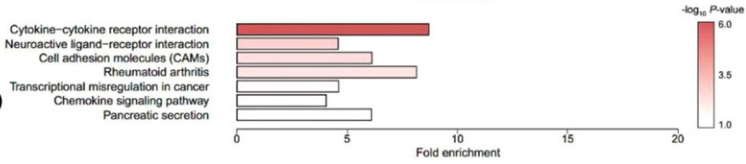
26

## 4 Functional enrichment

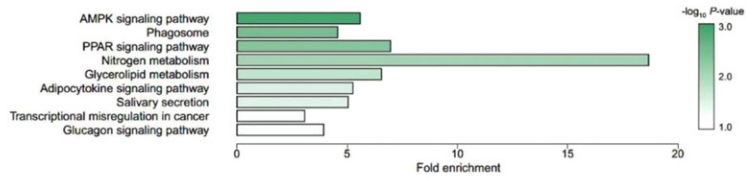
### 3 dpi-specific (Antiviral responses, Sensing pathways)



### Lung-specific (Immune responses)

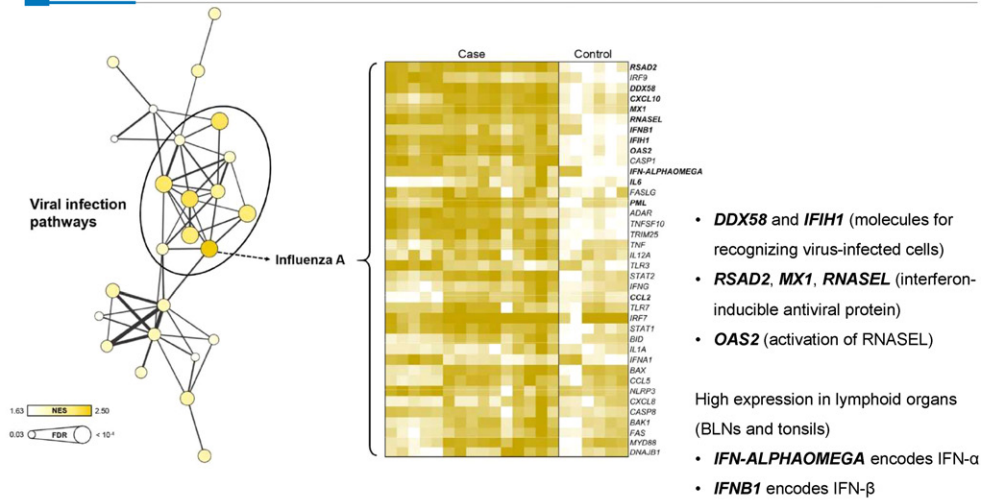


### BLN-specific (Lipid metabolism, Phagosome)



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## 5 Gene modulation (3 dpi-specific)

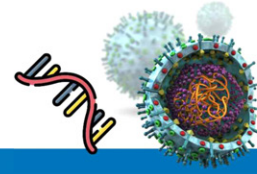


Common up-regulation of antiviral responses in target tissues

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Study 3



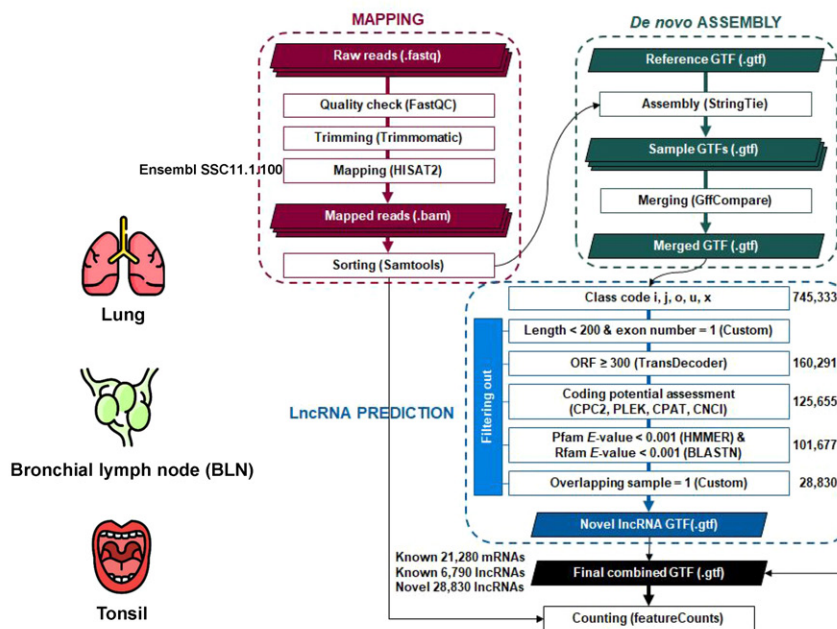
# Integrative time-serial networks for genome-wide lncRNA-mRNA interactions reveal interferon-inducible antiviral and T-cell receptor regulations against PRRSV infection

*Developmental and Comparative Immunology, 2023*



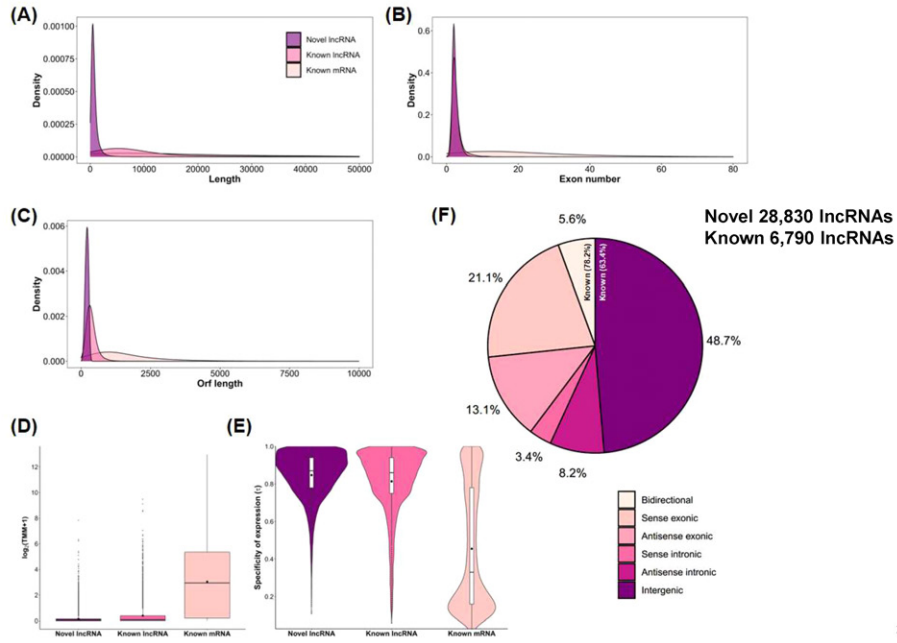
31

## 1 Data processing



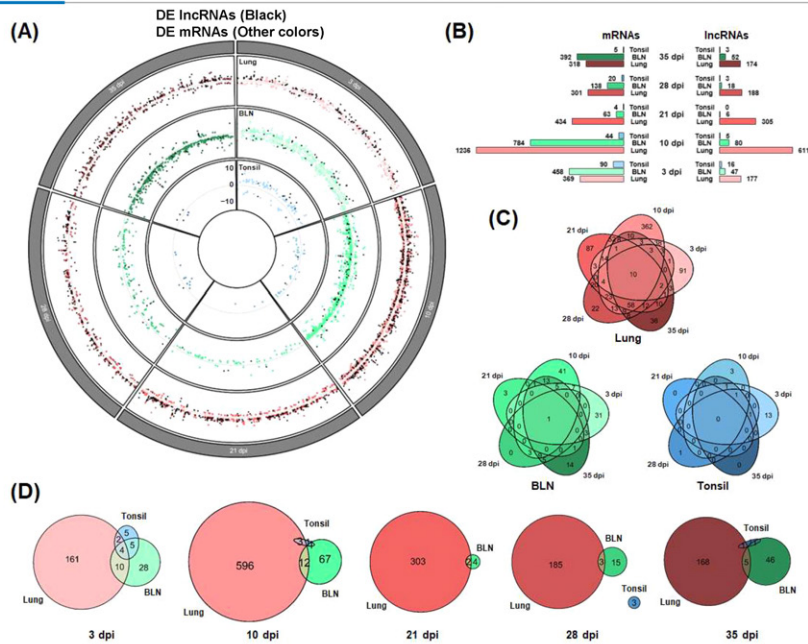
32

## 2 Characteristics of novel lncRNAs



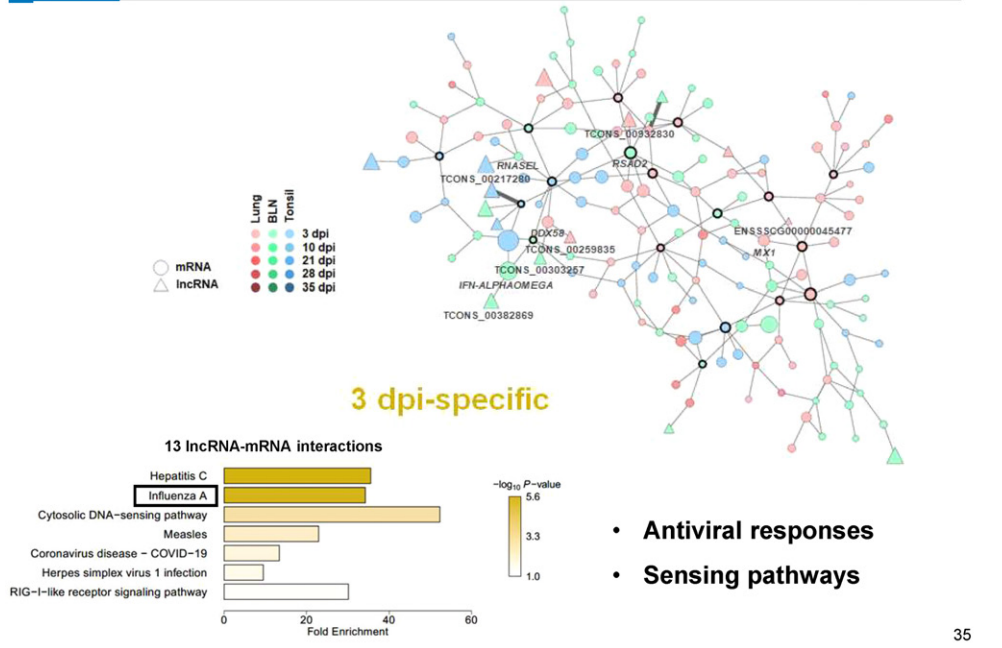
33

## 3 Time series of DE lncRNAs

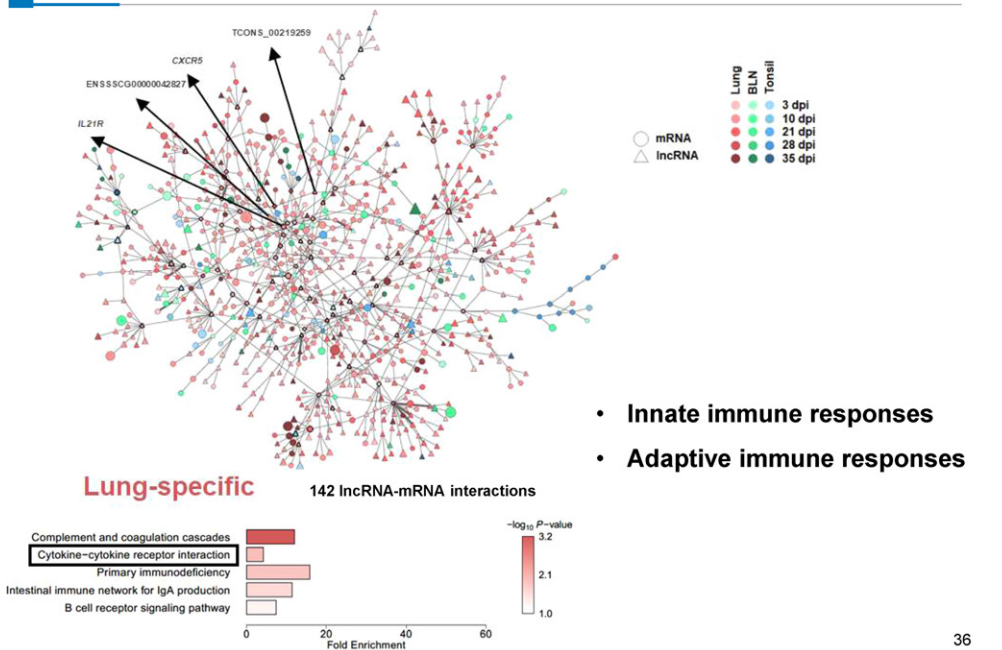


34

## 4 Gene co-expression network (3 dpi-specific)



## 5 Gene co-expression network (Lung-specific)



## 6 Modulation by lncRNAs

3 dpi

Lung

Network	lncRNA	Chr <sup>1</sup>	Location	Type	Target mRNA	Regulation	Corr <sup>2</sup>
Yellow	TCONS_00217280	13	204,833,179-204,841,410	Intergenic	<i>RNASEL</i>	trans	0.90
	TCONS_00382869	15	124,859,372-124,872,491	Intergenic	<i>IFN-ALPHAOMEGA</i>	trans	0.92
	TCONS_00259835	13	204,833,171-204,835,989	Intergenic	<i>DDX58</i>	trans	0.92
	TCONS_00303257	14	101,250,188-101,254,619	Sense exonic	<i>DDX58</i>	trans	0.92
	ENSSSCG00000045477	14	7,360,035-7,371,718	Intergenic	<i>MX1</i>	trans	0.90
	TCONS_00932830	8	130,590,032-130,591,714	Antisense exonic	<i>RSAD2</i>	trans	0.66
Red	TCONS_00219259	13	170,029,025-170,034,400	Antisense intronic	<i>CXCR5</i>	trans	-0.94
	ENSSSCG00000042827	4	69,183,628-69,404,114	Intergenic	<i>IL21R</i>	trans	-0.92

<sup>1</sup> Chromosome, <sup>2</sup> Correlation

- Interferon-inducible antiviral genes (*RNASEL*, *DDX58*, *MX1*, and *RSAD2*)
- Interferon gene (*IFN-ALPHAOMEGA*) (Positively regulated by lncRNAs)
- T cell receptor genes (*CXCR5* and *IL21R*) (Negatively regulated by lncRNAs)

*CXCR5*, encodes a receptor for CXCL13, plays a role in the process of B cell migration in lymph nodes

*IL21R* encodes receptor for IL21 that enhances proliferation of Th<sub>17</sub> and B cells

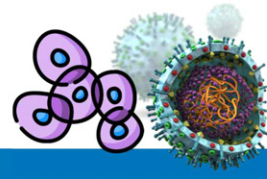
37

## Conclusions

- Interferon-inducible and an interferon genes related to antiviral and innate immune signaling were positively regulated by lncRNAs at early times in all tissues after PRRSV infection
- T-cell receptor genes, contributing changes in T and B cells, related to adaptive immune signaling were negatively regulated by lncRNAs at late times in the lungs

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## Study 4



# Single-cell transcriptomic landscape in BALF with varying PRRSV virulence levels reveals the mechanisms for lung recovery and bystander cell death regulation by exosomal miRNAs

Nature Communications, 2025

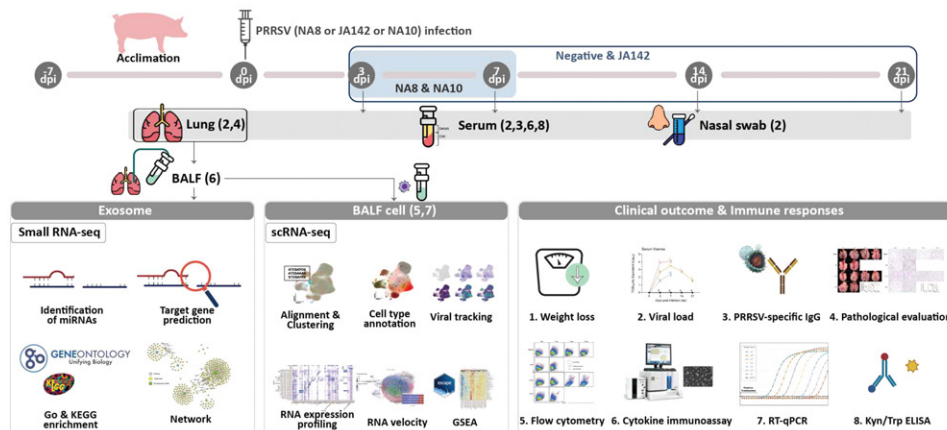


39

## 1 Experiment design & phenotypes

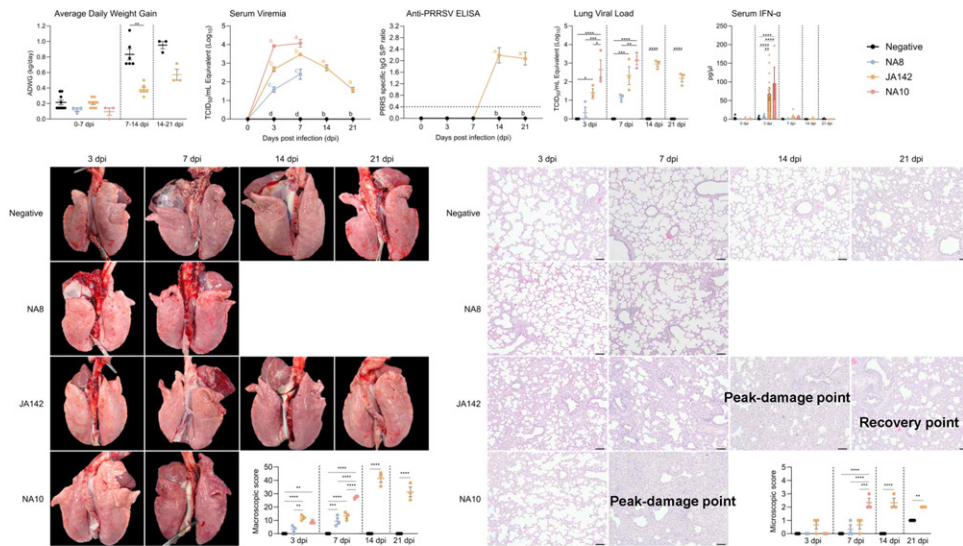
Landrace (♂) × Yorkshire (♀) × Duroc (♂)  
4-week-old piglets ( $n = 36$ )

Negative ( $n = 12$ )  
NA8: low virulence, mild ( $n = 6$ )  
JA142: intermediate virulence, acute, recoverable ( $n = 12$ )  
NA10: high virulence, peracute, non-recoverable ( $n = 6$ )



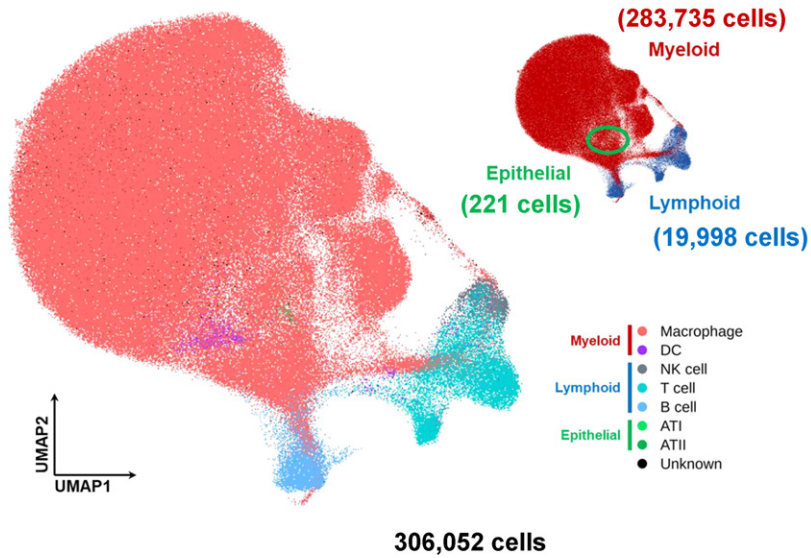
40

## 2 Phenotypes



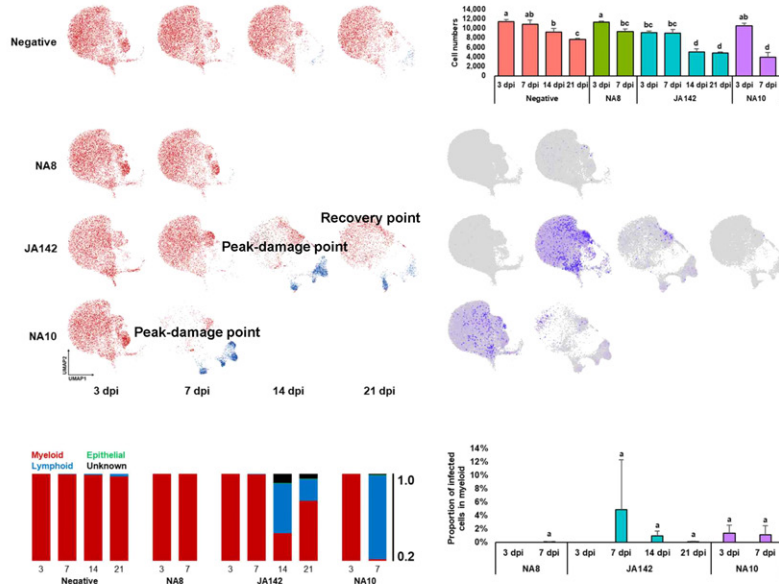
41

## 3 Single-cell landscape



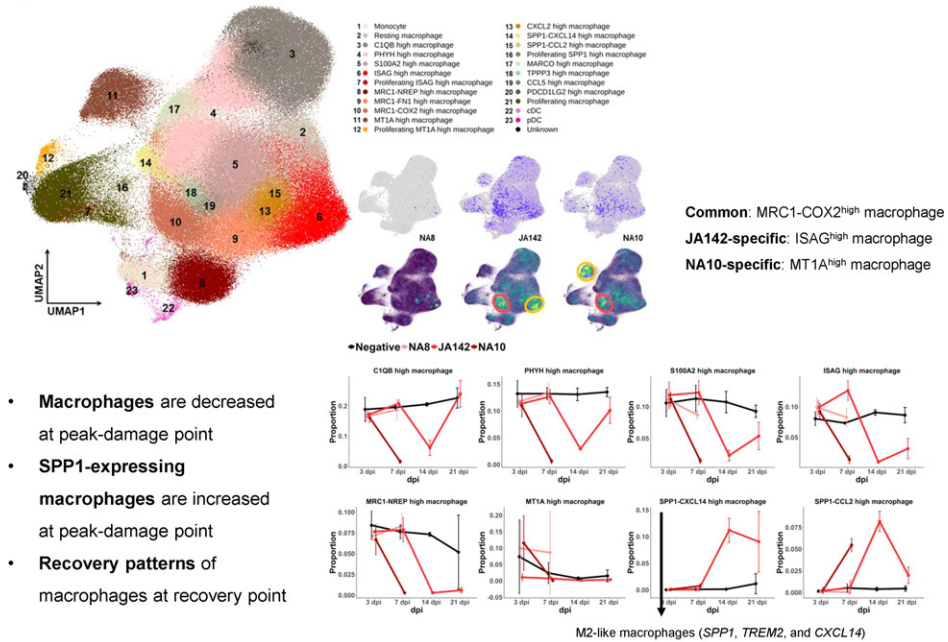
42

## 4 Cell distribution & Viral tracking



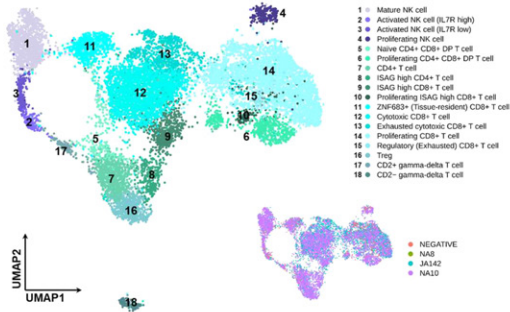
43

## 5 Macrophage and DC subpopulation



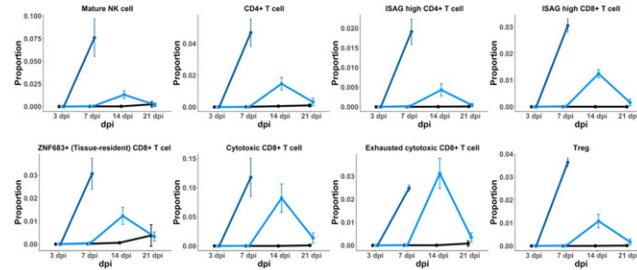
44

## 6 NK and T cell subpopulation



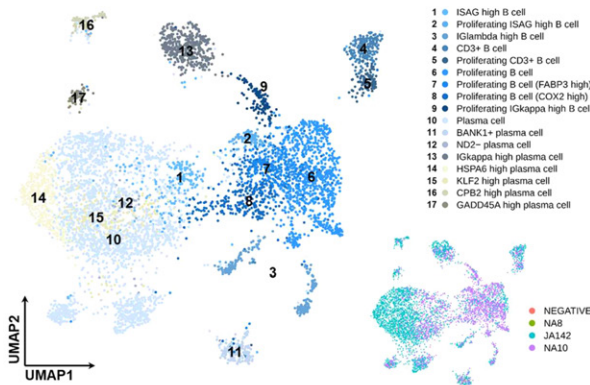
- NK cells and T cells are increased at peak-damage point (NA10 > JA142)
- NK cells and T cells are decreased at recovery point

•Negative = NA8 = JA142 = NA10



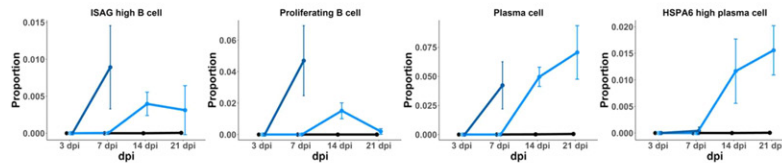
45

## 7 B cell subpopulation



- B cells are increased at peak-damage point (NA10 > JA142)
- Plasma cells are increased at peak-damage point
- B cells and plasma cells are increased at recovery point

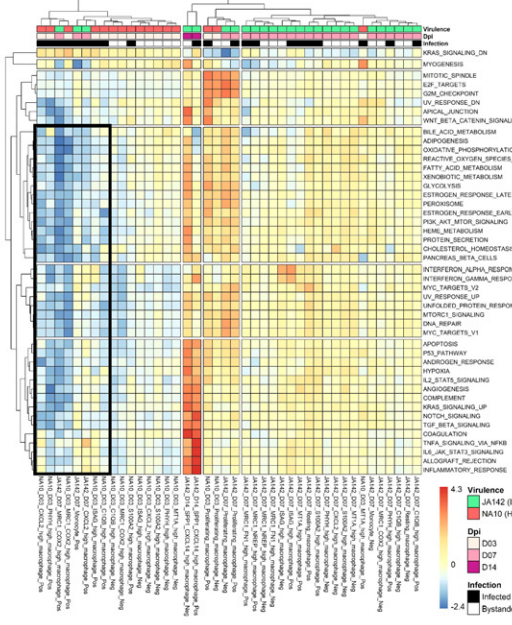
•Negative = NA8 = JA142 = NA10



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# 8 Functional enrichment

## Infected vs. bystander macrophages

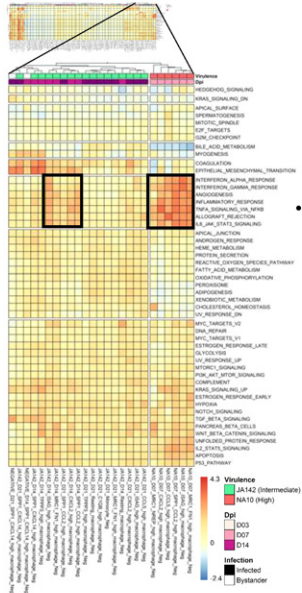


- Infected macrophages are down-regulated in metabolic, immune, and cell signaling (including apoptosis)
- (NA10 < JA142)

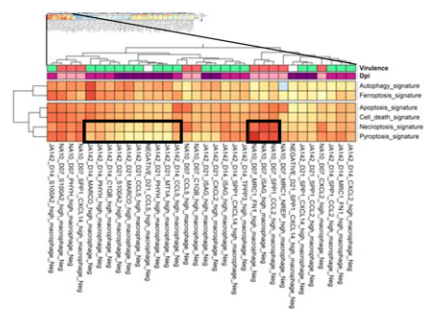
Metabolic signaling  
Immune signaling  
Cell signaling

# 9 Functional enrichment

## Bystander vs. negative macrophages



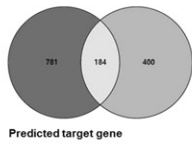
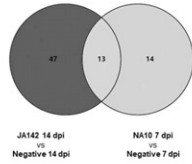
- Bystander macrophages are up-regulated in immune signaling at peak-damage point (NA10 > JA142)



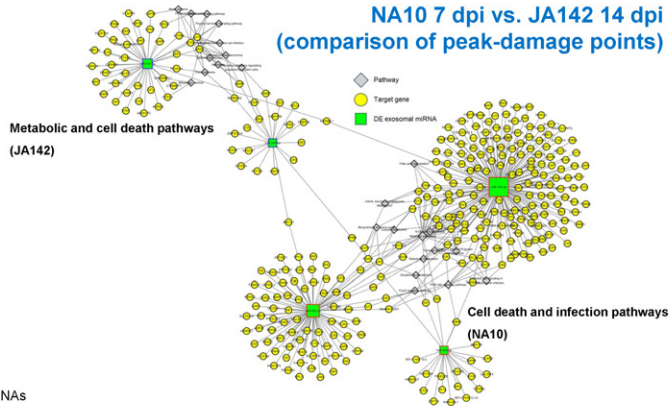
- Bystander macrophages are up-regulated in necroptosis and pyroptosis (inflammatory cell death) (NA10 > JA142)

# 10 Exosomal miRNAs

DE exosomal miRNA



- High cell death leads high expression of miRNAs
- Similar enrichment results (including cell death)

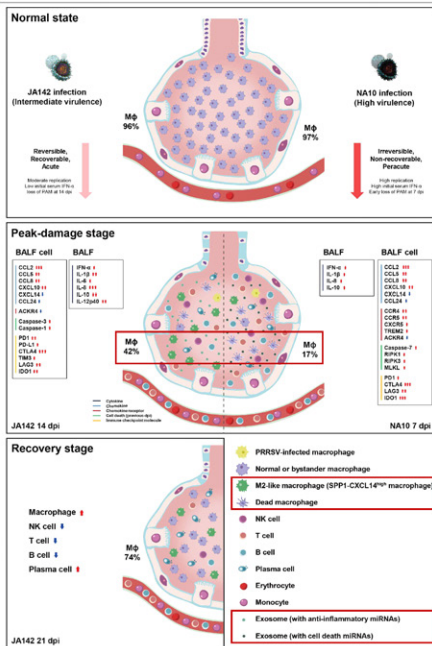


- miR-124-3p and miR-423-5p (in NA10) promote cell pyroptosis through regulation of NLRP3
- miR-145-5p, contributes anti-inflammation by targeting immunoreceptors, result in M2-like polarization in PRRSV infection (in JA142)
- miR-335-5p inhibits inflammatory and innate immune responses of macrophages (in JA142)

Exosomal miRNAs induced by NA10 contribute cell death (pyroptosis)

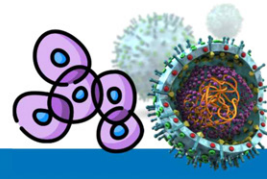
Exosomal miRNAs induced by JA142 contribute anti-inflammation and M2-like polarization

# Conclusions



- Large-scale comprehensive longitudinal changes in the immune cell composition of BALF with varying virulence levels for PRRSV
- Peak-damage points are different according to varying PRRSV virulence
- Anti-inflammatory M2-like macrophages contributes to lung recovery, regulated by exosomal miRNAs, from intermediate virulent infection (JA142)
- High virulent infection (NA10) accelerates bystander cell death (pyroptosis), regulated by exosomal miRNAs, leads to death

## Study 5



# Single-cell co-expression module-metabolite-microbe landscape in BALF with varying PRRSV virulence reveals tempo-graded macrophage immune collapse

Lim et al., 2026, *In progress*

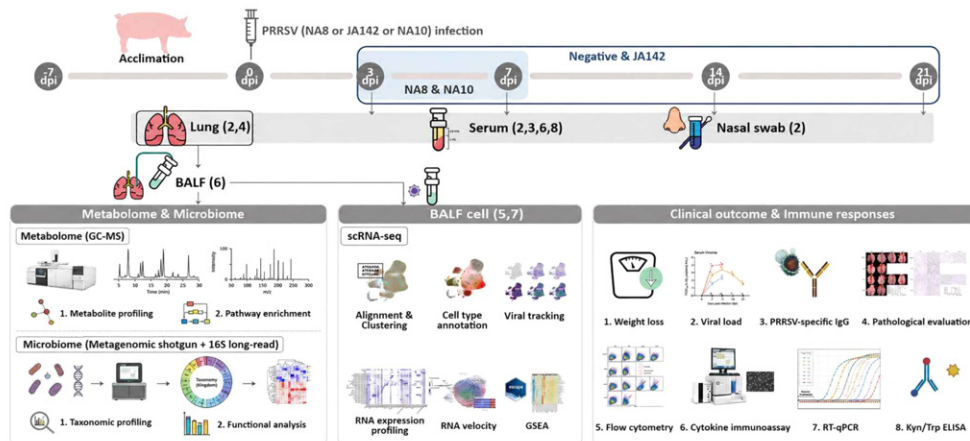


51

## 1 Experiment design & phenotypes

Landrace (♂) × Yorkshire (♀) × Duroc (♂)  
4-week-old piglets ( $n = 36$ )

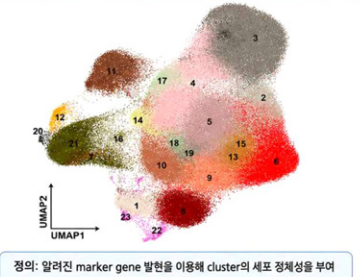
Negative ( $n = 12$ )  
NA8: low virulence, mild ( $n = 6$ )  
JA142: intermediate virulence, acute, recoverable ( $n = 12$ )  
NA10: high virulence, peracute, non-recoverable ( $n = 6$ )



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## 2 Gene module based analysis

### 1. Cell type marker 기반 해석



정의: 알려진 marker gene 발현을 이용해 cluster의 세포 정체성을 부여

#### 무엇을 보여주나?

- 큰 세포군이 어떻게 나뉘는지
- 각 cluster가 어떤 cell type인지
- 조직 내 세포 조성 변화

#### 장점

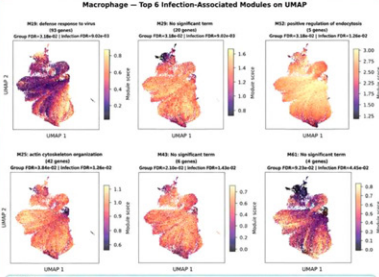
- 직관적이고 해석이 쉬움
- cluster naming이 명확함
- 주요 세포군 비교에 강함

세포 정체성 해석에서  
유전자 프로그램 해석으로 확장

#### 핵심 차이

- Left 이 cluster는 무엇인가?
- Right 이 cluster 안에서 어떤 프로그램이 켜지는가?

### 2. Gene-gene correlation / module 기반 해석



정의: 함께 움직이는 유전자 집합(module)의 경수를 각 세포에 투영하여 상태를 해석

#### 장점

- 같은 cluster 내부의 상태 차이를 더 잘 포착
- 연속적인 activation gradient 해석 가능
- marker 1-2개보다 안정적
- 기전적 해석에 유리
- cell type를 넘어 공통 프로그램 비교 가능

#### 정리

Cell-type marker 기반 분석은 '누가 누구인가'를 잘 보여주고, gene-module 기반 분석은 '무슨 프로그램이 켜졌는가'를 더 잘 보여준다. 두 접근은 경쟁 관계가 아니라 상호보완적이다.

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## 3 Gene module based analysis

Fig2F M19 — ISG antiviral cassette (Acute-Resolve)

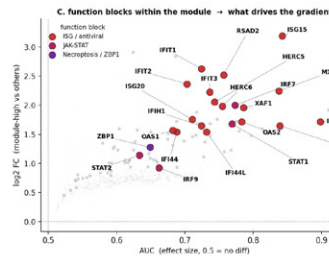
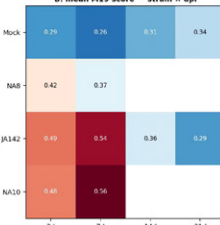
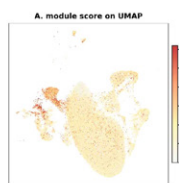
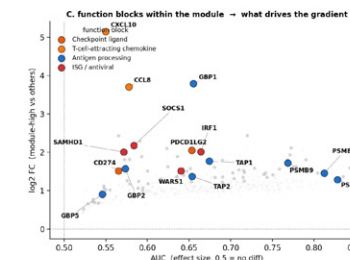
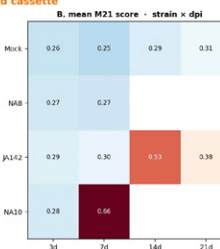
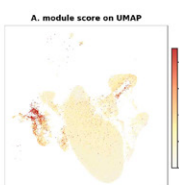


Fig2F M21 — PD-L1 / IFN $\gamma$  exhaustion-ligand cassette



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# 4 Gene module based analysis

Fig3F T\_M11 – ISG antiviral cassette (mirrors Mac\_M19)

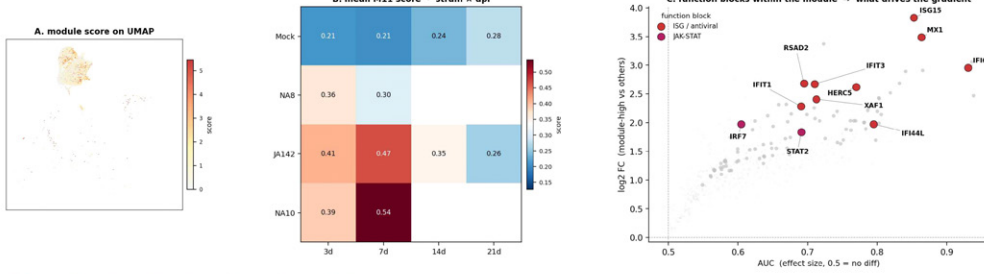
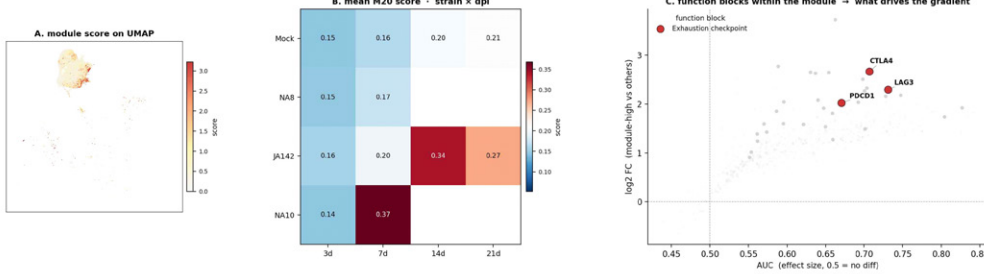


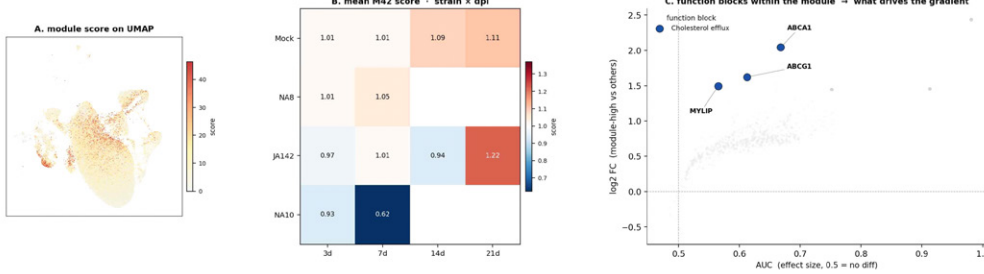
Fig3F T\_M20 – Exhaustion receiver (PD-1 · LAG3 · CTLA4)



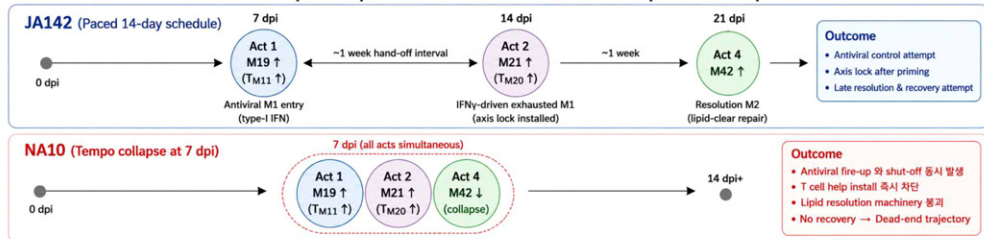
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# 5 Gene module based analysis

Fig2F M42 – Cholesterol efflux / M2 lipid resolution

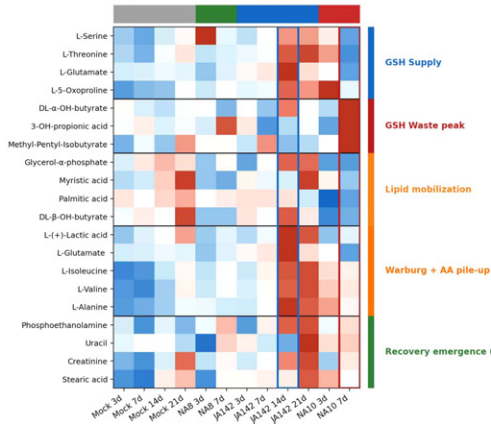


## Tempo Compression in NA10: Three Acts Collapsed into 7 dpi



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# 6 Metabolite analysis



### GSH Supply

**L-Serine, L-Threonine, L-Glutamate**  
 바이러스가 들어왔을 때 발생하는 세포 산화스트레스를 줄이기 위한 글루타치온 대사의 전구체임  
 JA142 14 21 에는 있으나 NA10에는 소실  
 NA10 항산화 능력의 합성 기질 한계(substrate limitation) 시사

### GSH Waste

**DL- $\alpha$ -OHB, 3-OH-propionic acid**  
 글루타치온 대사가 한계를 넘어 과부하로 터져버렸을 때 쏟아져 나오는 산화적 독성 물질  
 NA10 7일 차에 Block 1의 고갈과 동시에 폭발적으로 증가하며, 대식세포 조절성 세포사(PANoptosis)와 대사적 정합

### Lipid Mobilization

**Glycerol- $\alpha$ -P, Myristic acid, Palmitic acid,  $\beta$ -OHB**  
 파괴된 세포의 인지질과 표면활성제 찌꺼기들입니다.  
 14일 차에는 미생물의 먹이가 되지만, 21일 차에 살아남은 복구 대식세포(M42)가 발현하여 회복기작수행.

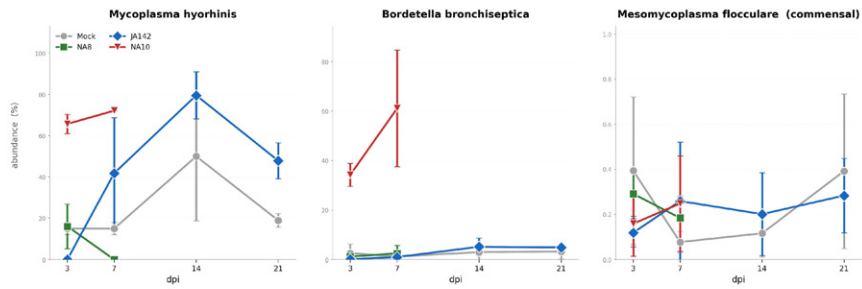
### Warburg & AA Catabolism

**Lactate(젖산), L-Ile, L-Val, L-Ala(아미노산)**  
 포도당을 불완전 연소시켜 젖산을 뿜어내고, 근육 단백질을 쪼개 아미노산을 사용.  
 JA142 감염 14일 차에 급증했다가 21일 감소

### Recovery Emergence

**Phosphoethanolamine, Uracil, Creatinine, Stearic acid**  
 폐 조직을 물리적으로 다시 짓는 회복의 마커  
 신규 인지질막 합성(Kennedy pathway) + 세포 증식(피리미딘 대사)  
 Creatinine = 에너지 항상성 회복  
 JA142 21일차 특이적 출현 / NA10군은 재생 시그니처 결손

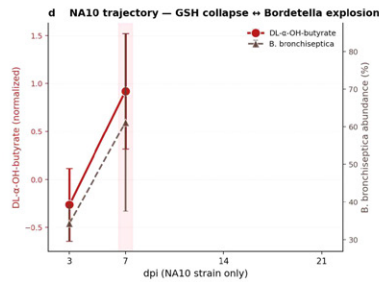
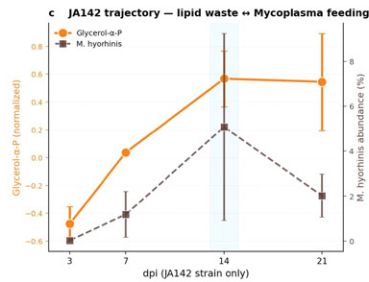
# 7 Microbiome analysis



long read - all strains

16S - Mock/NA8/JA142 + long read - NA10

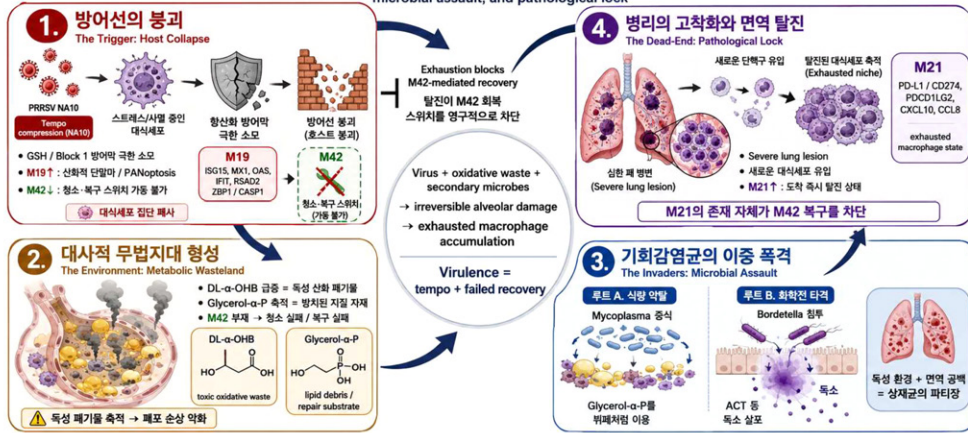
16S - all strains



# Suggestive mechanism

## The Vicious Cycle

PRRSV NA10-induced tempo compression drives host collapse, metabolic wasteland, microbial assault, and pathological lock



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## Study 6

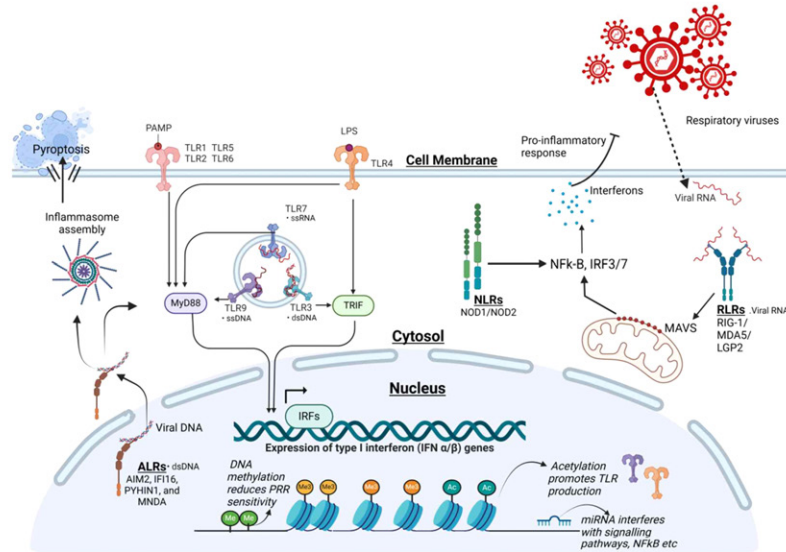
Identification of epigenomic alterations based on chromatin accessibility and histone modification against varying PRRSV virulence

Lim et al., 2026, *In progress*



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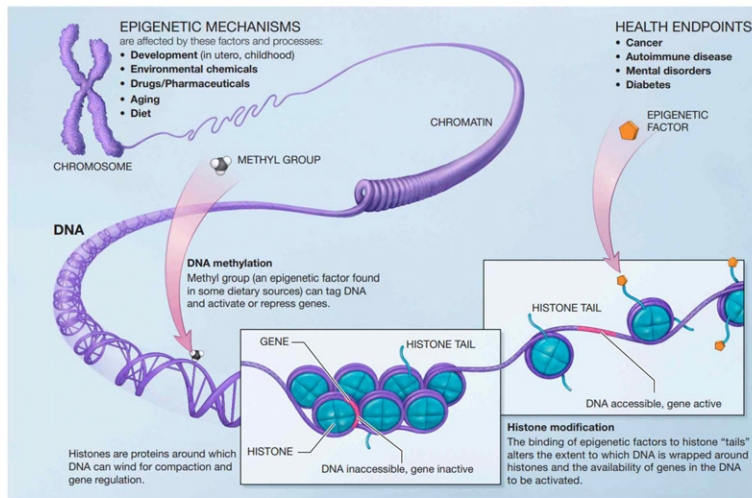
## Epigenetic alteration by viral infection



(Saha et al., 2025)

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## Epigenomics

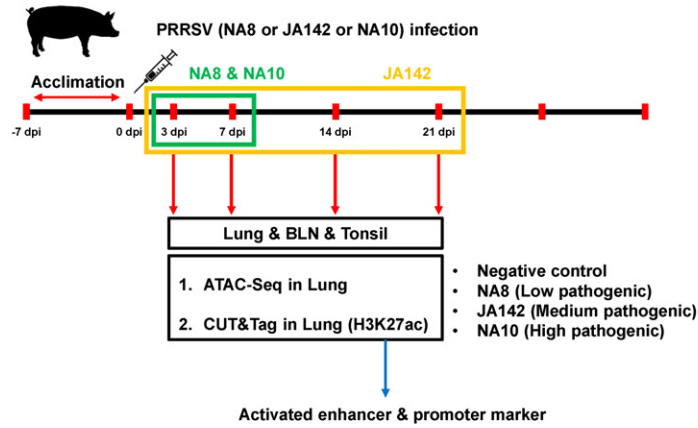


- ATAC-seq (Assay for Transposase-Accessible Chromatin using sequencing)
- ChIP-seq (Chromatin Immunoprecipitation Sequencing)

NIH

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# 1 Experimental design

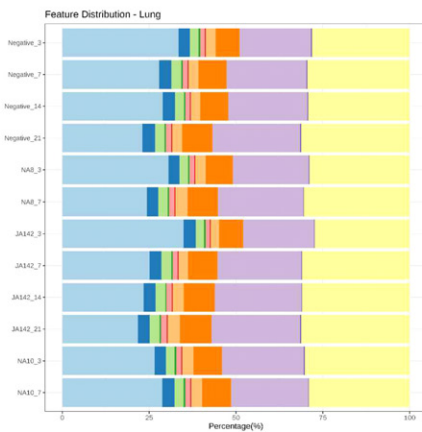


BALF: Bronchoalveolar lavage fluid

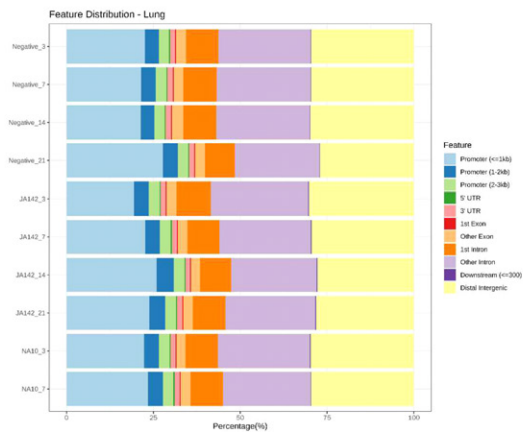
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# 2 Feature distribution (based on region)

## Chromatin accessibility (ATAC-seq)



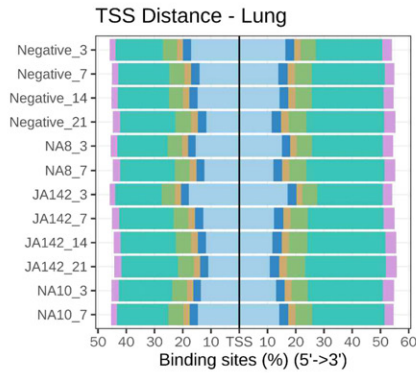
## Histone modification (CUT&Tag)



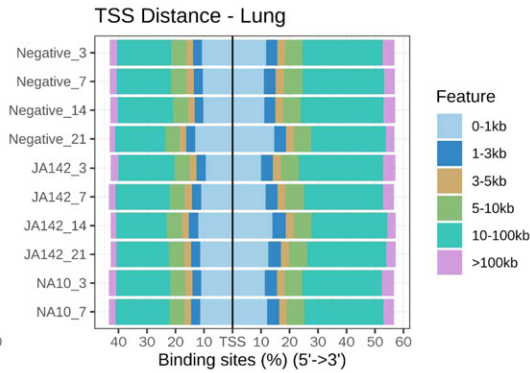
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## 4 Feature distribution (based on TSS)

### Chromatin accessibility (ATAC-seq)



### Histone modification (CUT&Tag)



TSS: transcription start site

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## 4 Differential regions

### Chromatin accessibility (ATAC-seq)

NA8 vs Neg 3 dpi, 0  
 NA8 vs Neg 7 dpi, 0  
 JA142 vs Neg 3 dpi, 25 up 1 down  
 JA142 vs Neg 7 dpi, 1 up  
**JA142 vs Neg 14 dpi, 9666 up 12 down**  
 JA142 vs Neg 21 dpi, 93 up 15 down  
**NA10 vs Neg 3 dpi, 296 up 12 down**  
**NA10 vs Neg 7 dpi, 45 up 35 down**

### Histone modification (CUT&Tag based on H3K27ac)

-  
 -  
 JA142 vs Neg 3 dpi, 18 up  
 JA142 vs Neg 7 dpi, 1 up  
**JA142 vs Neg 14 dpi, 2441 up 4972 down**  
 JA142 vs Neg 21 dpi, 25 up  
 NA10 vs Neg 3 dpi, 68 up  
**NA10 vs Neg 7 dpi, 206 up 78 down**

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## 5 Functional enrichment

### Chromatin accessibility (ATAC-seq)

#### JA142 vs Neg 14 dpi, promoter, **up** (top 10)

- Chemokine signaling pathway
- Osteoclast differentiation
- Natural killer cell mediated cytotoxicity
- T cell receptor signaling pathway
- Human cytomegalovirus infection
- B cell receptor signaling pathway
- Th17 cell differentiation
- Th1 and Th2 cell differentiation
- Human immunodeficiency virus 1 infection
- Apoptosis

#### NA10 vs Neg 3 dpi, promoter, **up**

- RIG-I-like receptor signaling pathway
- Hepatitis C
- Influenza A
- Coronavirus disease - COVID-19
- Measles
- Epstein-Barr virus infection
- Human papillomavirus infection

#### **Peracute**

### Histone modification (CUT&Tag based on H3K27ac)

#### JA142 vs Neg 14 dpi, promoter, **up** (top 10)

- Viral protein interaction with cytokine and cytokine receptor
- Th1 and Th2 cell differentiation
- T cell receptor signaling pathway
- Cytokine-cytokine receptor interaction
- Cell adhesion molecules
- Chemokine signaling pathway
- Natural killer cell mediated cytotoxicity
- Autoimmune thyroid disease
- PD-L1 expression and PD-1 checkpoint pathway in cancer
- Graft-versus-host disease

#### JA142 vs Neg 14 dpi, promoter, **down** (top 10)

- Cytoskeleton in muscle cells
- Focal adhesion
- ECM-receptor interaction
- PI3K-Akt signaling pathway
- Human papillomavirus infection
- Protein digestion and absorption
- Choline metabolism in cancer
- AGE-RAGE signaling pathway in diabetic complications
- Signaling pathways regulating pluripotency of stem cells
- Axon guidance

#### **Acute**

In **peracute high-virulence** PRRSV infection, there is insufficient time for epigenetic remodeling, whereas in **acute intermediate-virulence** infection, such remodeling is activated

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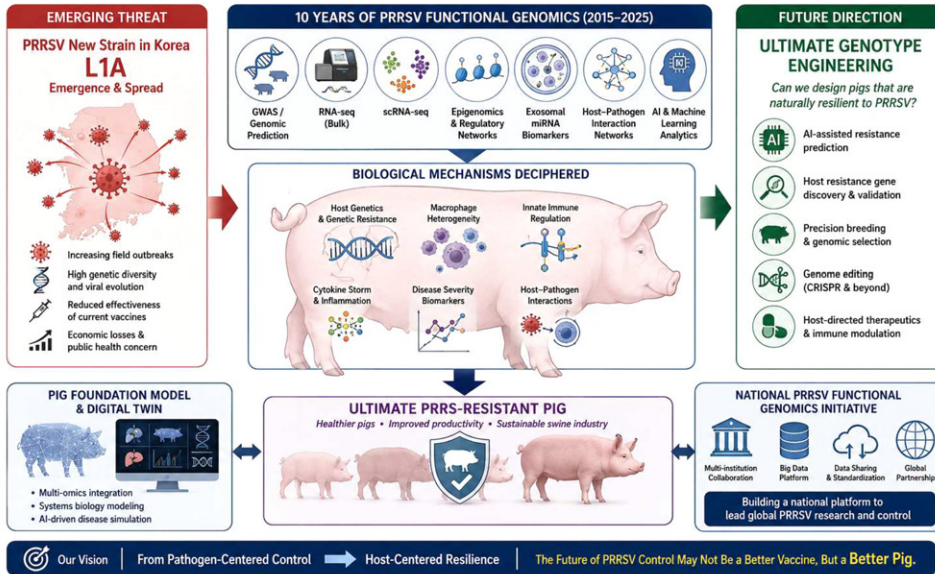
## Further Perspectives



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# From PRRSV Functional Genomics to Ultimate Genotype Engineering

## Engineering the Next Generation of Disease-Resilient Pigs Beyond Vaccination



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**Thank you!**



# From Livestock Environmental Exposure to Cellular Dysfunction: Mechanistic Toxicology in Porcine Cells

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(충북대학교)

(Chungbuk National University)

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- ▶ 2024~현재 충북대학교 축산학과 교수
- ▶ 2022~2024 고려대학교 동물분자생체공학연구소 연구교수
- ▶ 2018~2022 고려대학교 생명공학과 이학박사
- ▶ 2014~2018 고려대학교 생명공학과 이학사



# From Livestock Environmental Exposure to Cellular Dysfunction: Mechanistic Toxicology in Porcine cells

축산환경독성의 기전적 이해와 동물세포 기반 연구

2026.07.10



Wonhyoung Park, PhD  
Department of Animal Science  
Chungbuk National University

## Contents

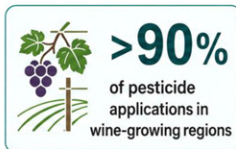
- 1. Background**
  - Environmental Exposure
  - Pig endometrium and trophectoderm
- 2. Study 1**
  - : Toxic effects of meptyldinocap on porcine maternal and fetal cells
- 3. Study 2**
  - : Toxic mechanisms of propiconazole in porcine endometrial epithelial cells
- 4. Study 3**
  - : Effect of Tolyfluanid on placental development in mouse
- 5. Ongoing study**

# 1 Environmental Exposure

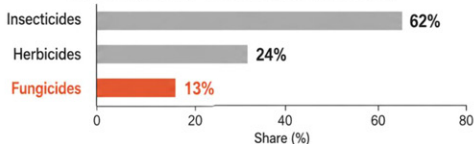
## Chapter 1. Background

### Present of pesticide study

#### Fungicide are widely used, but remain relatively understudied



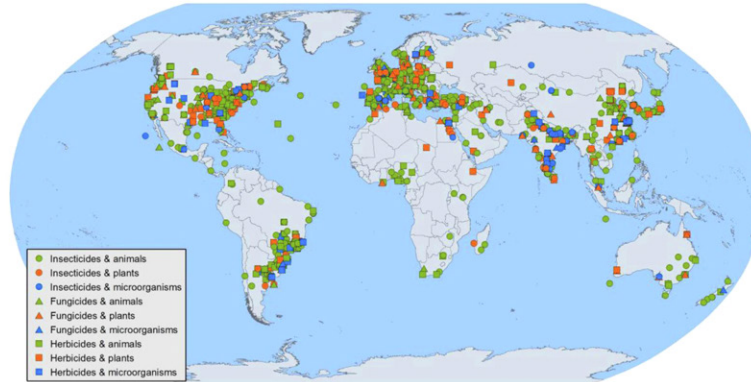
Share of pesticide-effect studies (1991–2013)



- ✓ Fungal diseases reduce crop yield and product quality
- ✓ Fungicides are widely used in crop and feed-crop production
- ✓ Despite broad use, fungicides have received relatively limited research attention
- ✓ Fungicides should be considered an important but still underexplored class of environmental toxicants

Sources: Eurostat (2024 EU pesticide sales); Zubrod et al., *Environ. Sci. Technol.* 2019.

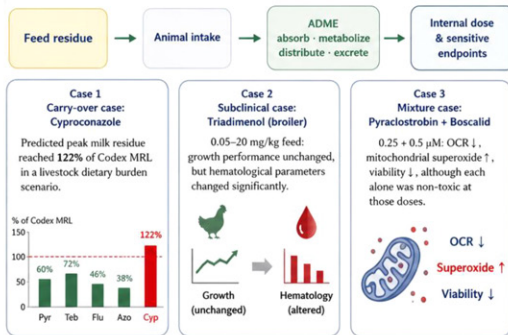
█ Negative effects of fungicide on non-target organisms



Wan, NF., Fu, L., Dainese, M. *et al.* Pesticides have negative effects on non-target organisms. *Nat Commun* 16, 1360 (2025).

█ Exposure to fungicide

Fungicide residues in livestock and biological concern



• MRLs manage commodity-level residues, but do not describe the absorbed dose, metabolites, or tissue-specific exposure.

✓ Feed burden can shift residues into animal products: cyproconazole was predicted to exceed the milk Codex MRL under some scenarios.

✓ No growth effect does not mean no toxicity: low-dose triadimenol altered hematological endpoints in broilers.

✓ Low-dose mixture exposure can unmask toxicity: boscalid + pyraclostrobin impaired mitochondrial function despite individually non-toxic doses.

✓ Therefore, sensitive biological endpoints may respond before overt production loss or carcass-residue signals are evident.

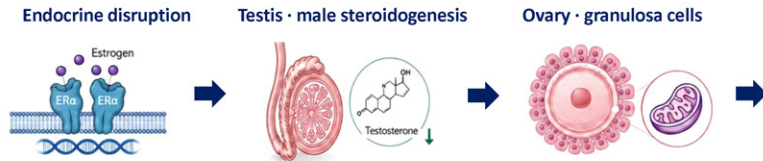
Residue level → intake → ADME → internal dose → sensitive cellular response  
 Zhang et al., 2022, *J Food Compos Anal*; Tang et al., 2024, *Food Chem Toxicol*; Carbone et al., 2023, *Molecules*

\*MRL: Maximum Residue Level; ADME: absorption, distribution, metabolism and excretion

⇒ Residue monitoring is the starting point, but biological risk should also be interpreted through ADME, low-dose repeated exposure, and mixture effects.

■ Risk of fungicide

Fungicides can disturb reproductive systems



- ✓ **Cyproconazole and epoxiconazole** may interfere with mammalian CYP-related endocrine pathways and suppress ERα-mediated signaling.
- ✓ **Prochloraz** alters fetal testis development by disrupting steroidogenesis and reducing testosterone synthesis.
- ✓ **Mancozeb** impairs oocyte quality and damages granulosa/oocyte function, partly linked to mitochondrial dysfunction.

Research perspective

: **From endocrine disruption to reproductive cellular toxicity**

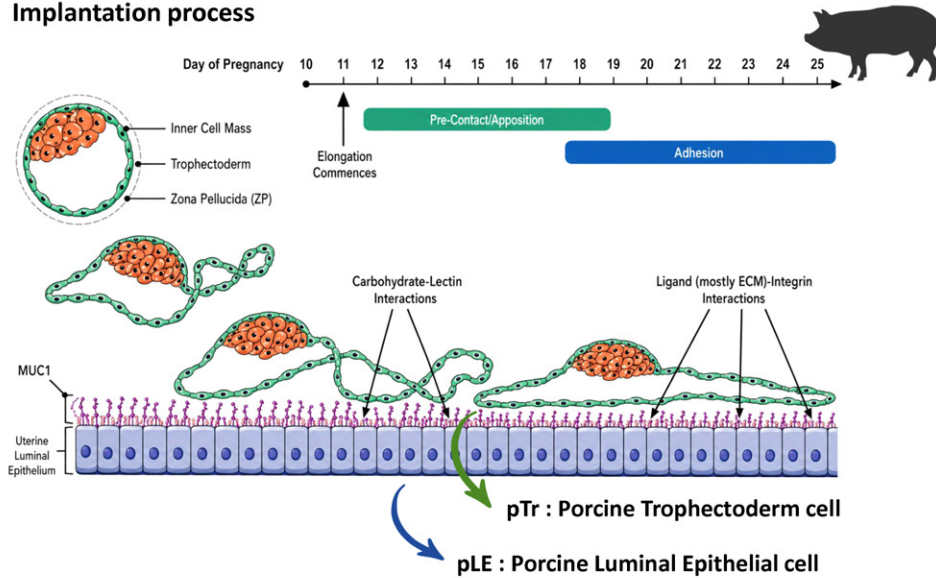
Fungicide risk is not limited to residue detection; reproductive mode-of-action evidence should also be considered.

**2** Pig Endometrium and Trophectoderm

■ Implantation process of pig



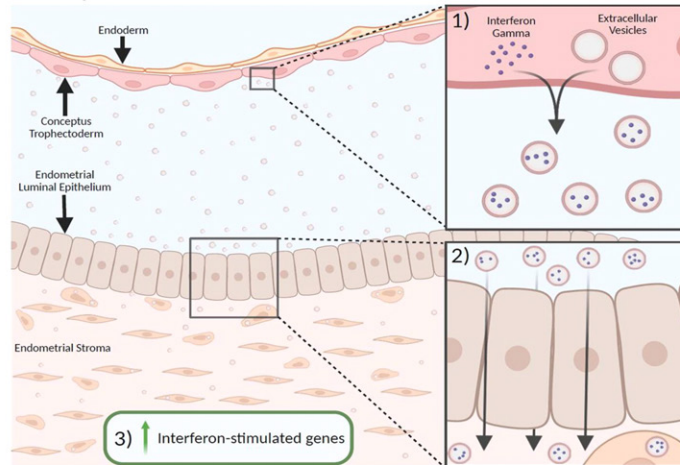
Implantation process



■ Maternal-Fetal Interaction

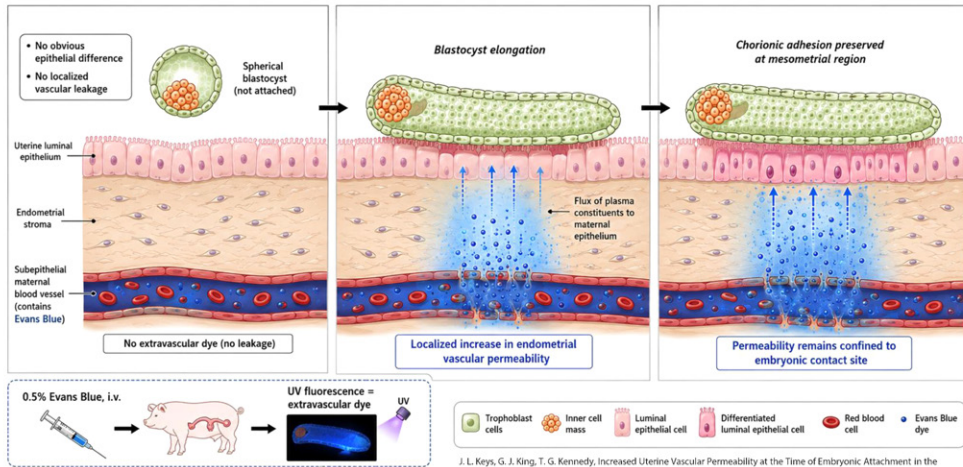


Conceptus-maternal Interaction



Biol Reprod, Volume 111, Issue 1, July 2024, Pages 174–185. <https://doi.org/10.1093/biolre/iaae044>  
The content of this slide may be subject to copyright; please see the slide notes for details.

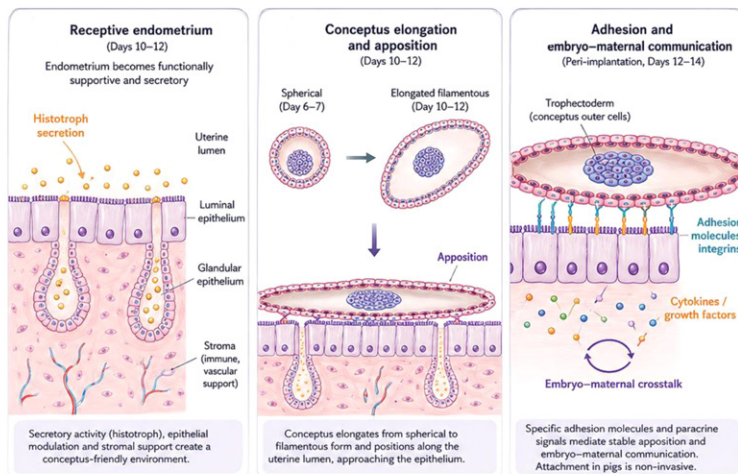
Localized increase in **endometrial vascular permeability** during implantation in the gilt



The same physiological route that supports nutrient and signal exchange during implantation may also create a window of susceptibility to circulating toxicants.

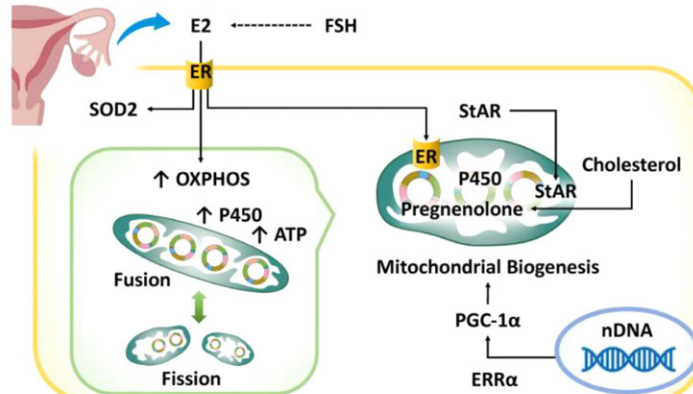
Endometrial Receptivity

- ✓ Successful implantation also depends on whether the uterus is prepared to accept the embryo.
- ✓ Uterine receptivity is the transient state in which the endometrium becomes competent for embryo attachment and support.



■ Energy Dependency of Endometrium

- ✓ The implantation window requires extensive cellular remodeling of the endometrium, including epithelial differentiation, secretory transformation, angiogenesis
- ✓ These processes are energetically supported by mitochondrial ATP production and tightly coordinated with mitochondrial  $Ca^{2+}$  handling, redox balance, and quality control.



Keke Zhang, Enfeng Zhang, Kun Wu, Wenxiu Cheng, Shaobin Wei, Mitochondrial homeostasis: A key regulator in endometrial physiology and pathology, Drug Discovery Today, Volume 30, Issue 12, 2025

- ✓ Toxicant-induced mitochondrial dysfunction may therefore compromise endometrial receptivity before overt tissue-level reproductive failure occurs.

**3** Experimental Results

Study 1.

■ Experimental architecture



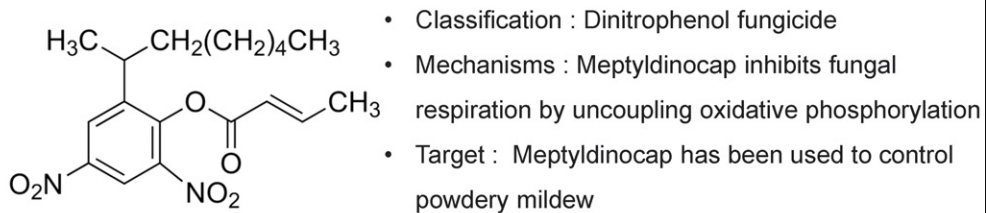
## Experimental architecture

Three fungicides, one mechanistic question: how is implantation-cell function disrupted?

Study 1 Meptyldinocap	Study 2 Propiconazole	Study 3 Tolyfluanid
<b>Model</b> pLE / pTr	<b>Model</b> pLE	<b>Model</b> Mouse
<b>Mechanistic focus</b> Mitochondrial uncoupling Ca <sup>2+</sup> imbalance ER stress	<b>Mechanistic focus</b> Azole fungicide mitochondrial / endocrine-related signals cellular dysfunction	<b>Mechanistic focus</b> ETC-related mitochondrial stress implantation / placental outcomes <i>in vivo</i> validation

Study 1.

■ Meptyldinocap



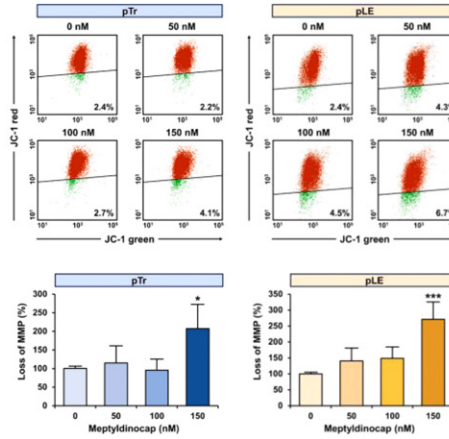
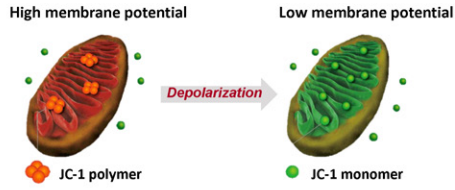
- In South Tyrol, meptyldinocaps were detected in many public places. A maximum meptyldinocap level of 0.15 mg/kg was detected in grass samples
- In Japan, dinitrophenol compounds have been detected in 177 river-water samples, indicating a widespread exposure to the environment

Study 1.

Result 1 Meptyldinocap induces mitochondrial membrane depolarization in pTr and pLE cells



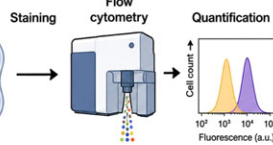
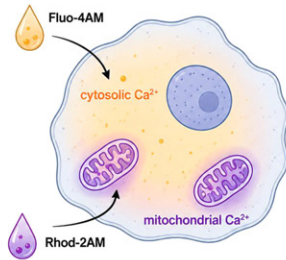
Mitochondria integrity



✓ JC-1 analysis showed increased MMP loss in both pTr and pLE cells, indicating early mitochondrial membrane destabilization.

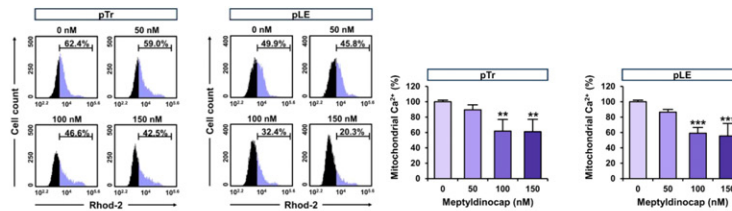
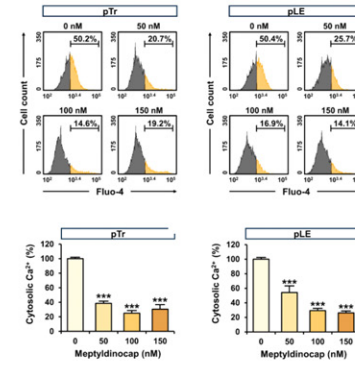
Study 1.

Result 2 Mitochondrial disturbance is accompanied by Ca<sup>2+</sup> depletion



Higher fluorescence = higher Ca<sup>2+</sup> level

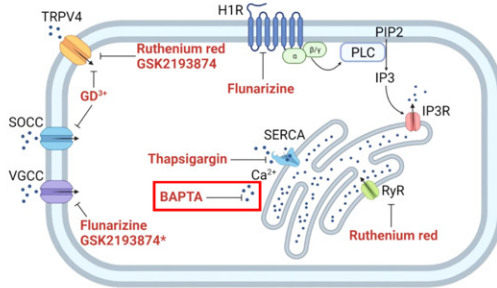
- Fluo-4AM: cytosolic Ca<sup>2+</sup> indicator
- Rhod-2AM: used to assess mitochondrial Ca<sup>2+</sup> accumulation



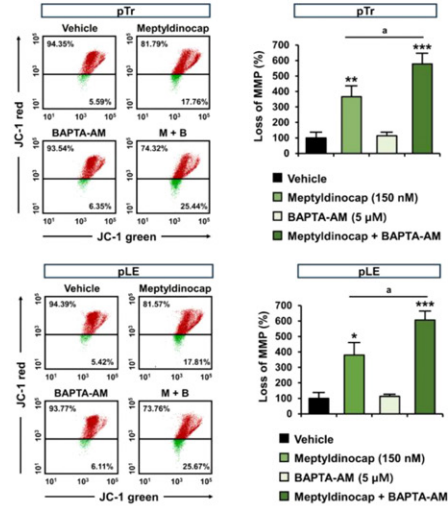
Study 1.

Result 3

Calcium depletion aggravates meptyldinocap-induced mitochondrial depolarization



\*BAPTA : cytosolic calcium chelator

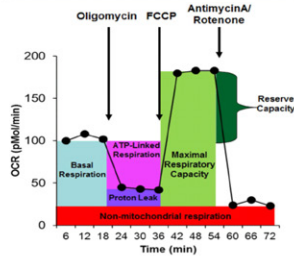
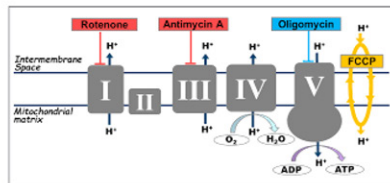


✓ BAPTA-AM further increased MMP loss under meptyldinocap exposure, linking Ca<sup>2+</sup> depletion to mitochondrial depolarization.

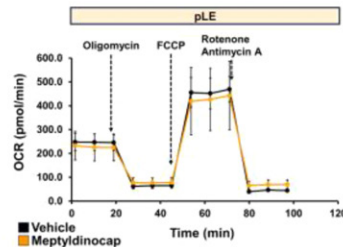
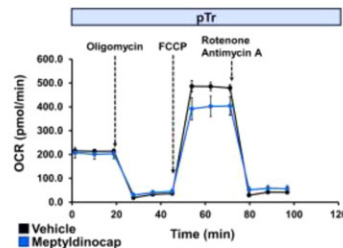
Study 1.

Result 4

Meptyldinocap compromises mitochondrial respiratory capacity, particularly in pTr cells



\*OCR : Oxygen consumption rate

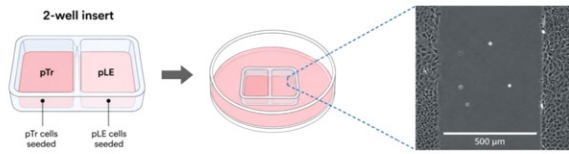


✓ OCR analysis showed reduced maximal respiration in pTr cells

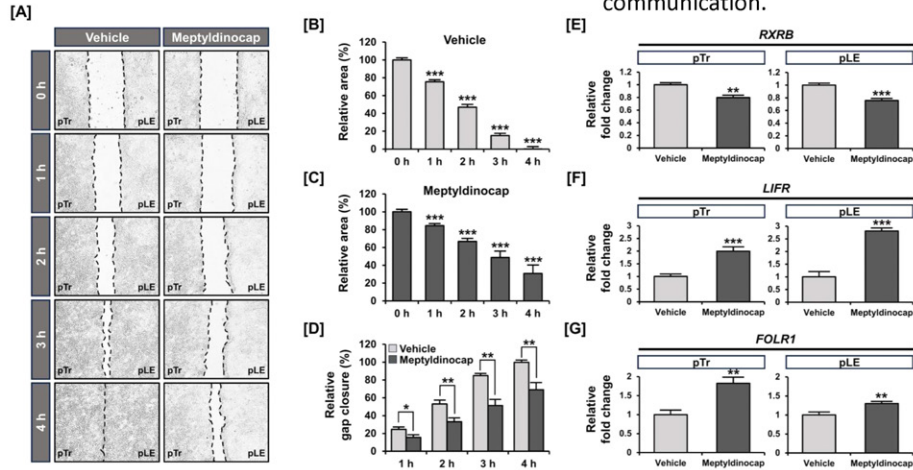
Study 1.

Result 5

Mitochondrial and Ca<sup>2+</sup> disruption translates into impaired pTr-pLE interaction

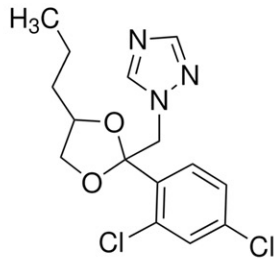


✓ Meptyldinocap delayed gap closure between pTr and pLE cells and altered pregnancy-related genes, suggesting impaired implantation-associated communication.



Study 2.

Propiconazole



- Classification : Triazole fungicide; DMI/SBI Class I
- Mechanisms : Propiconazole inhibits fungal C14-demethylase (CYP51/ERG11), blocking ergosterol biosynthesis and disrupting membrane integrity
- Target : Broad-spectrum control of foliar fungal diseases, including rusts, powdery mildew, leaf spots,

- In U.S. streams, propiconazole was detected in 17% of 103 samples from 29 streams in 13 states; detected fungicide levels ranged from 0.002 to 1.15 µg/L
- In Belgium, propiconazole was detected in surface-water samples from 16 locations and in wastewater-treatment-plant effluents, with reported levels of 1.9–178.3 ng/L
- In Korea, residues were monitored in greenhouse-grown cabbage, shallot, and spinach; initial residues were 1.46–6.26 mg/kg and dissipated by 90–99% within 14 days

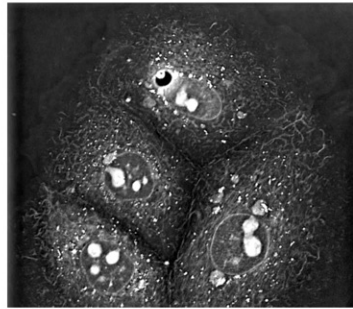
Study 2.



**Result 1 Propiconazole reduced mitochondrial contents and activity in pLE cells**

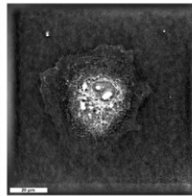
Live-cell imaging and Mito Tracker staining indicate reduced mitochondrial abundance and activity after propiconazole exposure

✓ **Representative live-cell image**

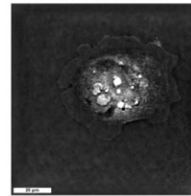


Label-free imaging shows abundant mitochondrial structure in untreated pLE cells

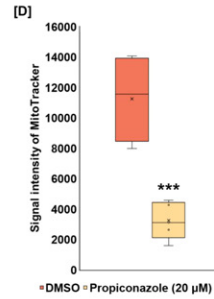
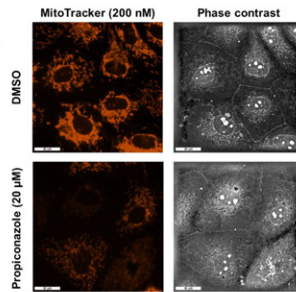
DMSO



Propiconazole (20 μM)



✓ **MitoTracker Fluorescence assay**



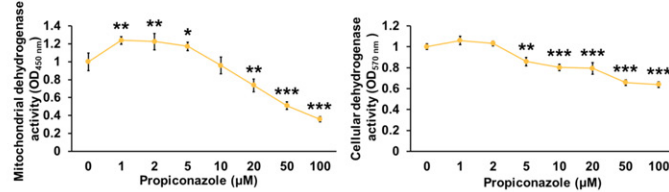
• DMSO • Propiconazole (20 μM)

Study 2.

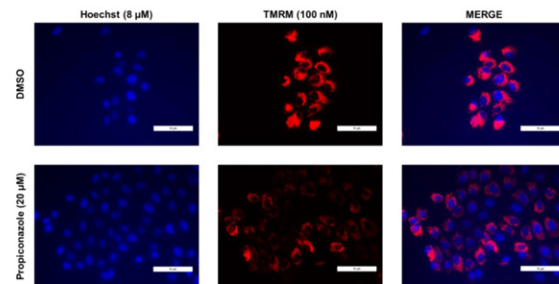


**Result 2 Propiconazole impaired mitochondrial membrane potential in pLE cells**

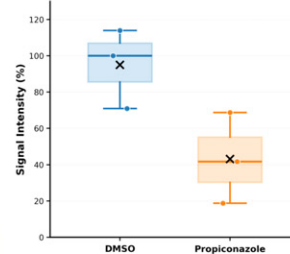
✓ **Metabolic enzyme activity**



✓ **TMRM-based  $\Psi_m$  detection**



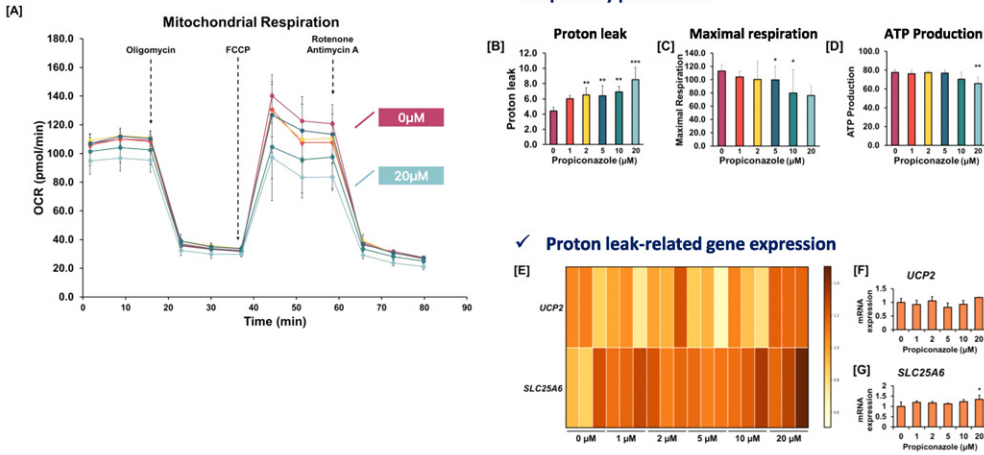
✓ **TMRM intensity**



⇓ TMRM accumulates in polarized mitochondria; reduced red fluorescence reflects MMP depolarization

Study 2.

**Result 3 Propiconazole disrupts mitochondrial respiration and increases proton leak**

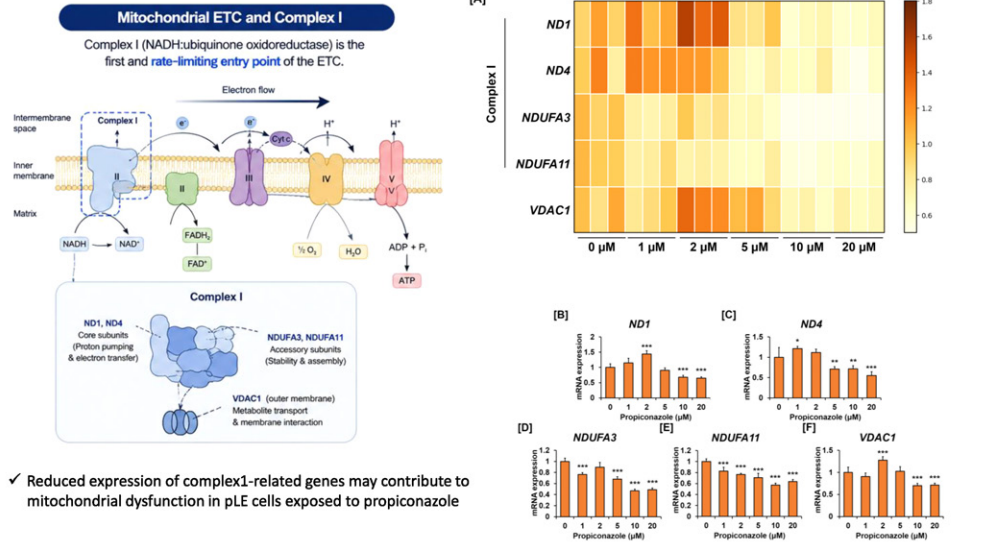


⇒ Propiconazole impairs mitochondrial respiration in pLE cells, characterized by increased proton leak and reduced respiratory efficiency

Study 2.

**Result 4 Propiconazole downregulated mitochondrial Complex I-related genes**

Heatmap and qPCR analyses showed dose-dependent suppression of Complex I-associated transcripts, suggesting impaired mitochondrial electron transport



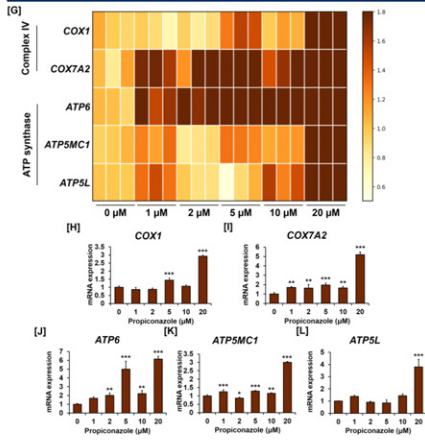
### Study 2.



## Result 5 pLE cells exhibit transcriptional adaptive responses to impaired OXPHOS

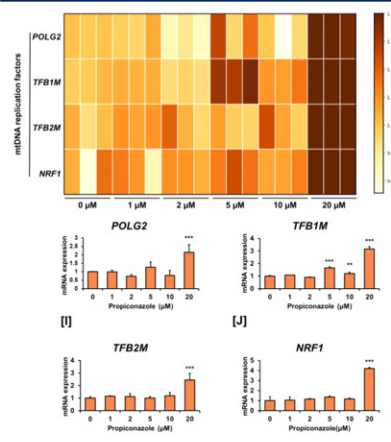
OXPHOS-related and mtDNA regulatory transcripts were upregulated, suggesting a compensatory response to impaired mitochondrial respiration.

### Adaptive induction of OXPHOS component genes



Genes associated with Complex IV and ATP synthase were elevated after propiconazole exposure

### Upregulation of mtDNA maintenance and transcription factors



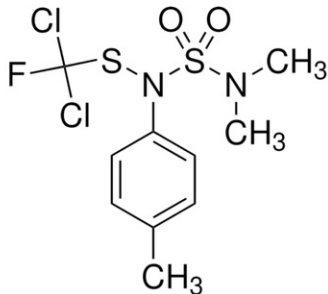
Increased expression of POLG2, TFB1M, TFB2M, and NRF1 suggests activation of mitochondrial biogenesis and mtDNA regulatory pathways.

- ✓ These transcriptional changes suggest that pLE cells mount a compensatory mitochondrial stress response to propiconazole-induced OXPHOS impairment.

### Study 3.

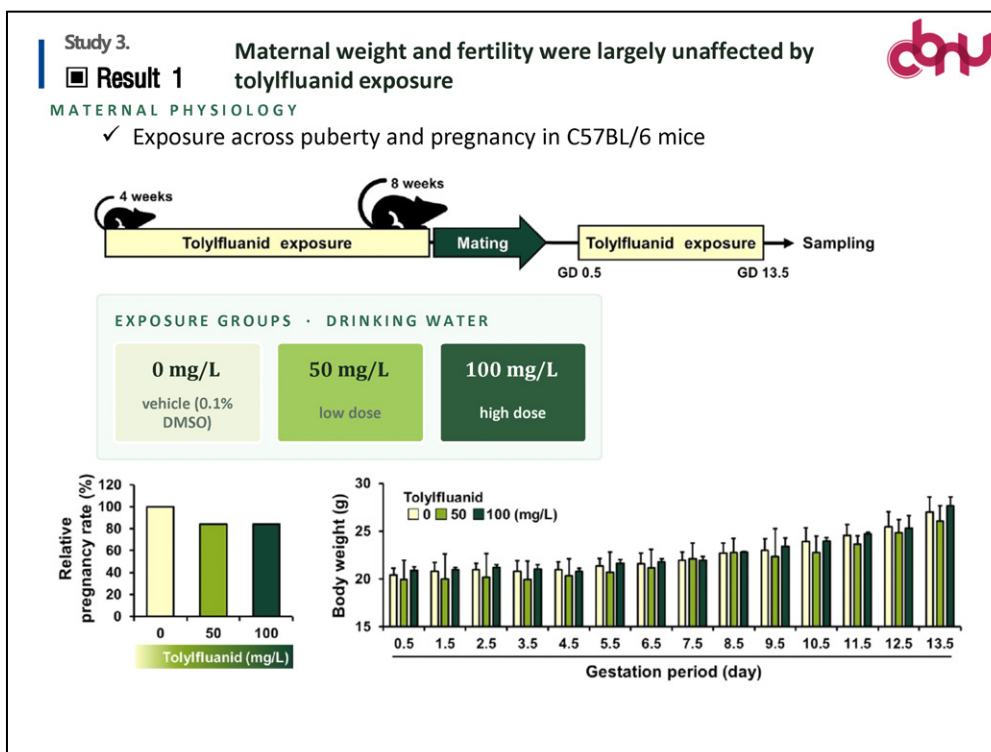
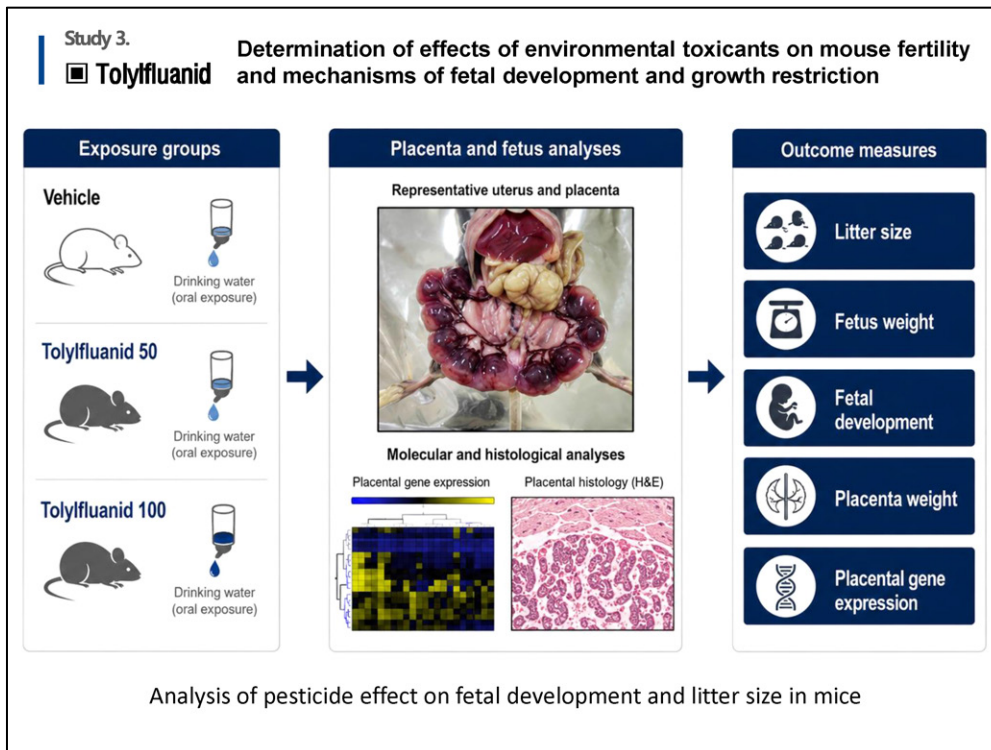


## Tolyfluanid



- Classification : Sulfamide fungicide
- Mechanisms : Tolyfluanid disrupts mitochondrial respiration by inhibiting enzymes in the ETC
- Target : ornamental plants against gray mold (Botrytis), against late blight and powdery mildew

- tolyfluanid and its metabolites were detected in groundwater near agricultural areas, and exposure may be possible through vegetables used with tolyfluanid
- a residual level of tolyfluanid up to 13.3 mg/kg has been confirmed in strawberries grown in a greenhouse in Norway
- the internationally estimated daily intake (IEDI) of tolyfluanid is estimated to be 0.043 mg/kg for adults and 0.048 mg/kg for children

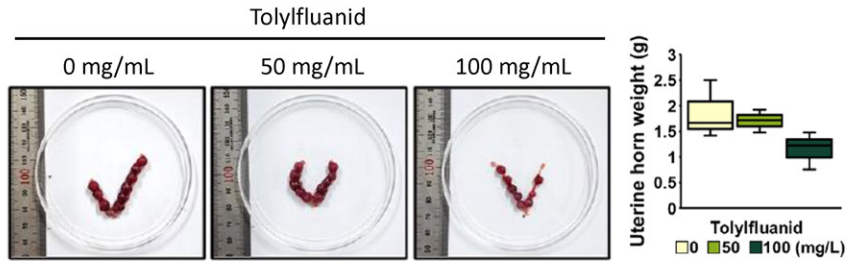


Study 3.

Result 2 Underdeveloped fetuses and lighter uterine horns at 100 mg/L



GROSS MORPHOLOGY



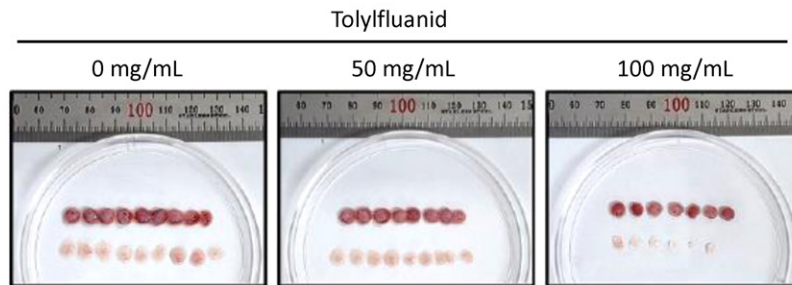
- ✓ Uterine horn weight : Decreasing trend at the highest dose (pregnant mice)
- ✓ Non-pregnant mice : Uterine horn weight significantly reduced (Suppl.)

Study 3.

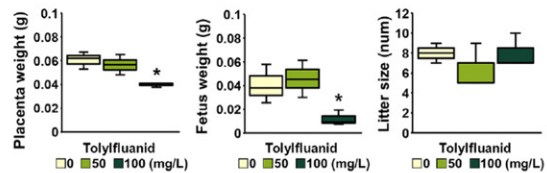
Result 3 Significant fetal and placental growth restriction



FETAL & PLACENTAL GROWTH



- ✓ Placenta weight ↓ significant at 100 mg/L
- ✓ Fetus weight ↓ significant at 100 mg/L
- ✓ Litter size unchanged across all doses



→ Number maintained, size restricted: a fetal growth restriction (FGR) phenotype

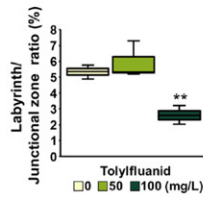
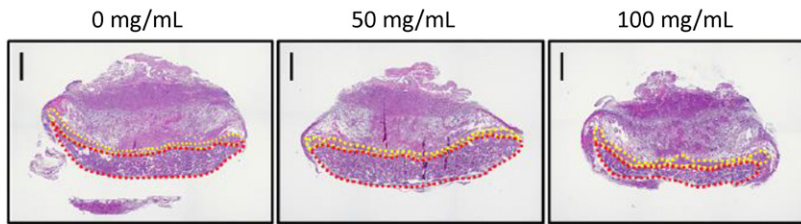
Study 3.

**Result 4** Reduced labyrinth-to-junctional-zone ratio impairs exchange



PLACENTAL ARCHITECTURE

Tolyfluamid



WHAT THE H&E SHOWS

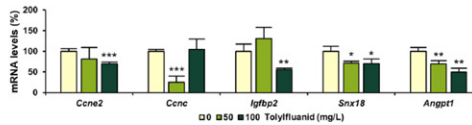
- ✓ **Labyrinth / junctional zone ratio ↓** significant at 100 mg/L (\*\*)
- ✓ **Labyrinth = exchange zone** site of maternal–fetal nutrient & gas transfer
- ✓ **Junctional zone** energy storage & hormone production

Study 3.

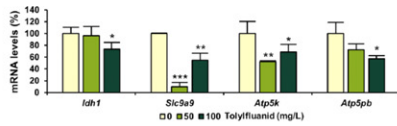
**Result 5** Coordinated dysregulation: development ↓, mitochondria ↓, inflammation ↑



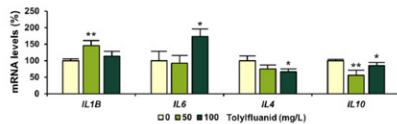
PLACENTAL GENE EXPRESSION



- ✓ **Development genes ↓**  
Ccne2, Ccnc (proliferation); Igfbp2 (growth); Angpt1 (angiogenesis); Snx18 (nutrient transport)

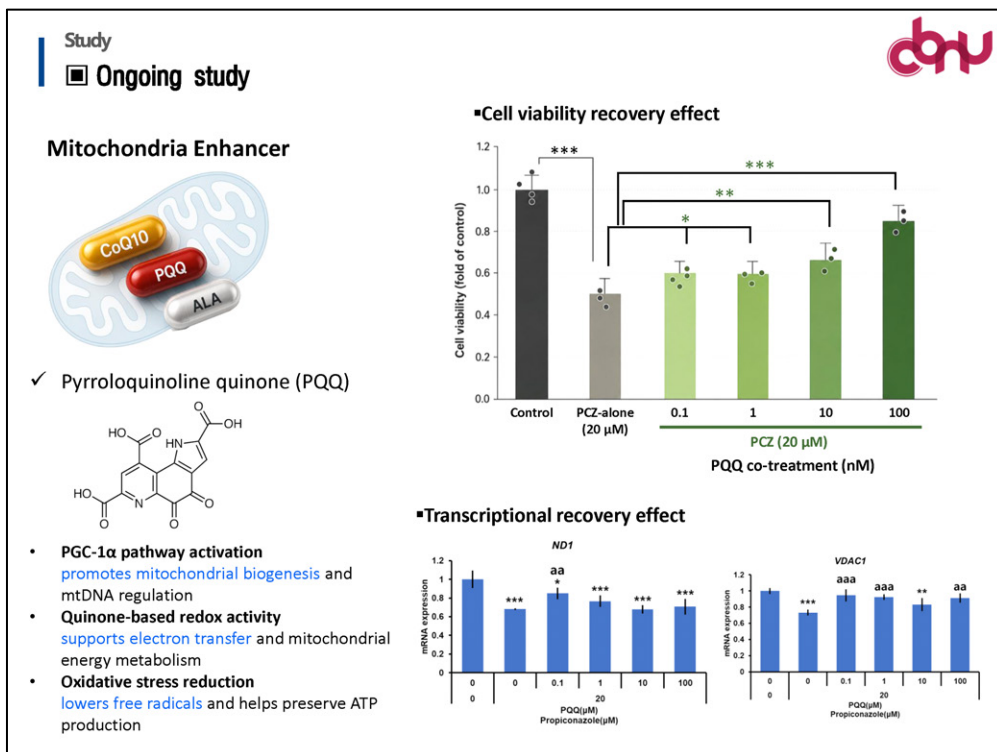
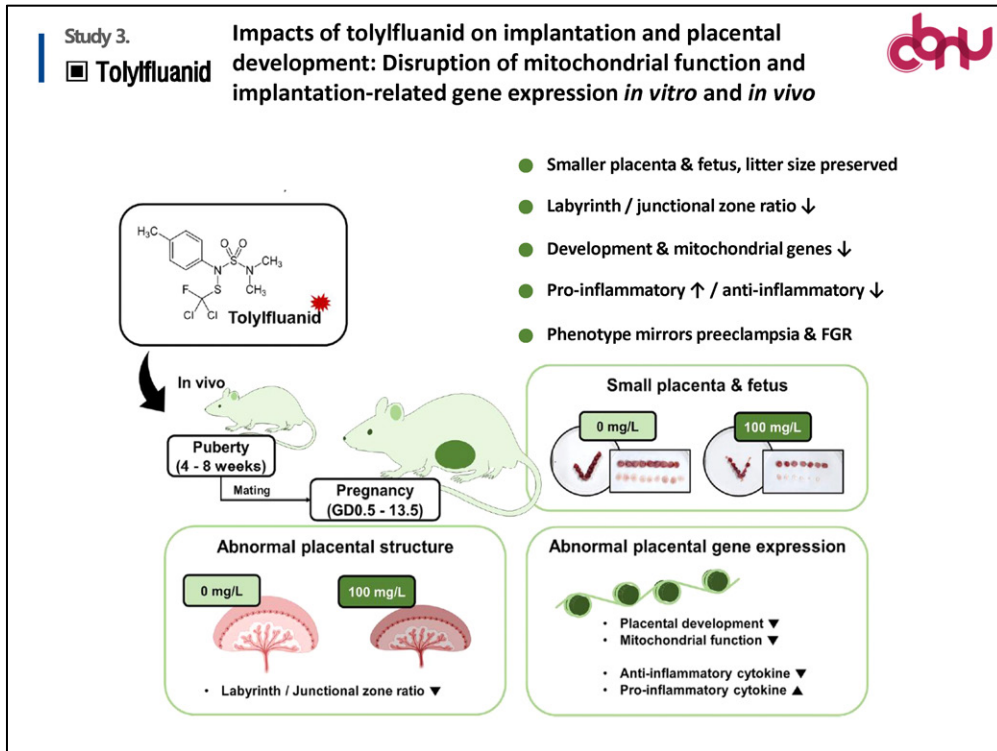


- ✓ **Mitochondrial genes ↓**  
Idh1, Slc9a9, Atp5k, Atp5pb



- ✓ **Inflammatory imbalance**  
pro-inflammatory IL1b, IL6 ↑ / anti-inflammatory IL4, IL10 ↓

- ✓ **Similarity with PE / FGR**  
Snx18, Idh1, Slc9a9 also fall in human preeclampsia & FGR placentas



# Current Research Trend in Xenotransplantation

황 정 호

Hwang, Jeong Ho

(건국대학교)

(Konkuk University)

## Curriculum Vitae

- ▶ 2026~현재 건국대학교 생명과학대학 동물자원전공 조교수
- ▶ 2023~2026 국가독성과학연구소 책임연구원
- ▶ 2024~2026 국가독성과학연구소 전북첨단바이오연구본부 중대동물융합연구센터 센터장
- ▶ 2018~2024 국가독성과학연구소 전북분소 동물모델연구그룹 그룹장
- ▶ 2016~2022 국가독성과학연구소 선임연구원
- ▶ 2007~2013 건국대학교 생명공학과 이학박사
- ▶ 2001~2007 건국대학교 동물생명과학대학 농학사



# Current Status of Xenotransplantation Research

*From Genetically Engineered Pigs to Clinical Trials*

Jeong Ho Hwang, Ph.D.

Department of Animal Science and Technology, Konkuk University

Bio Organ Research Center | Korea Institute of Toxicology | Konkuk University

## Contents

- 01 Introduction: rationale of xenotransplantation
- 02 Transgenic Pig Development — Global Current Status
- 03 Our Research: Pig-to-NHP Xenotransplantation in Korea
- 04 Key Results — Kidney, Heart, Cornea
- 05 Challenges & Future Strategy

## The Current Status of Organ Transplantation in South Korea

(Ministry of Health and Welfare, KONOS, 2024)

**54,789**

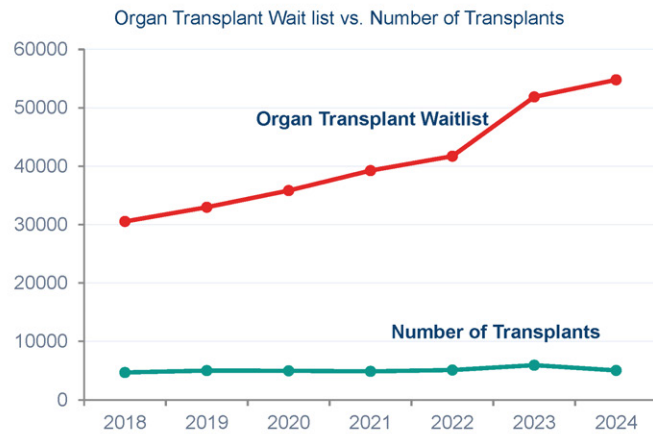
Organ transplant candidates  
(As of 2024)

**7.96 p/day**

On the transplant waiting list  
Average daily deaths

**11%**

Compared to the Number of People  
on the Waiting List  
Annual Transplant Rate



KONOS (국립장기조직혈액관리원), Ministry of Health & Welfare, 2024

## Global Organ Shortage: An Unmet Medical Crisis

**~106,000**

Waitlisted in  
the US alone

**17/day**

Americans die  
waiting

**>800,000**

Deaths/yr attributable  
to organ failure (global)

**<10%**

Demand met by  
cadaveric donation

Organ transplantation is the only definitive treatment for end-stage organ failure — yet global demand vastly exceeds supply.

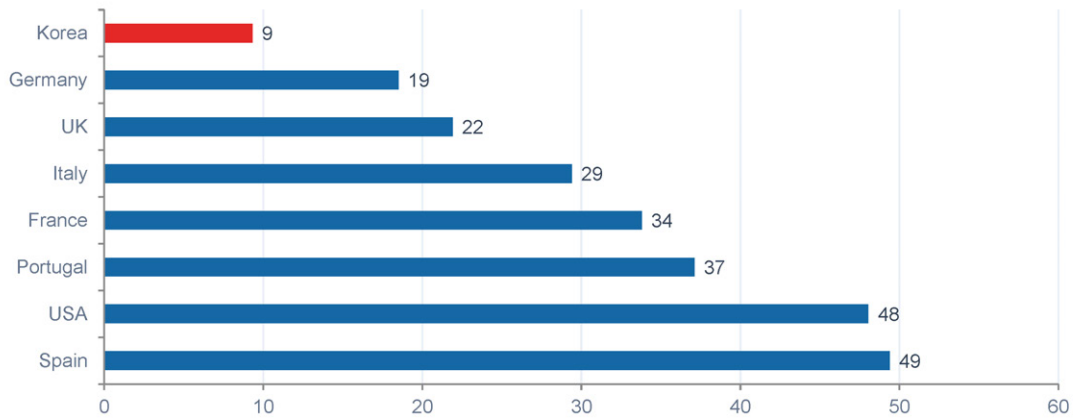
**The xenotransplantation opportunity: unlimited supply of GE pigs → off-the-shelf organs on demand**

### Pig advantages:

- Similar organ size
- Rapid breeding cycle (5 months)
- Customizable genome
- SPF housing feasible
- 100+ million pigs available globally

UNOS, 2024; WHO Global Observatory on Donation & Transplantation, 2024

## Brain-Death Donation Rate: Korea vs. World (per million population)



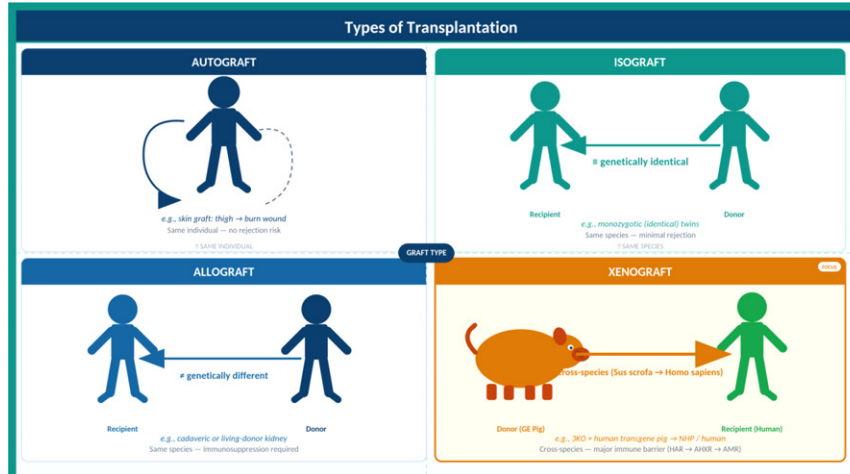
Korea 9.32 pmp = only 1/5 of Spain. Cadaveric organ donation alone cannot meet demand. Xenotransplantation is the only scalable solution.

WHO Global Observatory on Donation & Transplantation; KONOS 2024

# 01

## Introduction: Rationale

# What is xenotransplantation?



## Why the Pig? — Ideal Xenograft Donor

### Anatomical Compatibility

Organ size matches humans; cardiovascular physiology is similar to humans

### Genetic Editability

CRISPR/Cas9 enables precise multi-gene knock-out and knock-in modifications

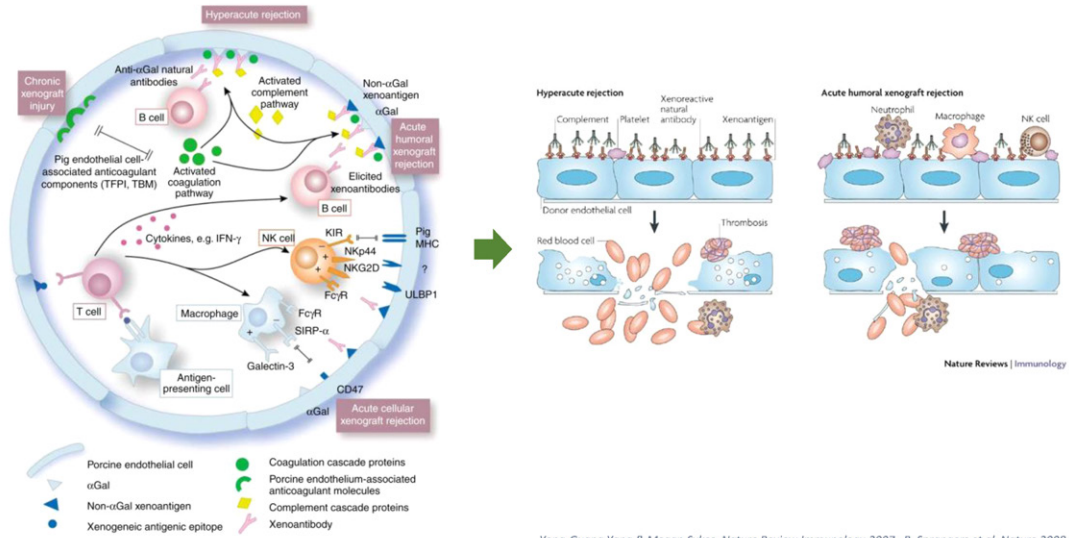
### Short Gestation & Large Litter

Rapid production of transgenic animals for research scale-up and GMP production

### Zoonosis

PERV-inactivated pigs (69-gene edit) show no PERV transmission to primates  
Germfree available

# Limitation of Xenotransplantation



# Limitation of Xenotransplantation

**Pigs are the best xenograft donor species: organ size, physiology, breeding speed, genetic tractability**

Hyperacute Rejection (HAR)	Acute Humoral Rejection (AHR)	TMA / Coagulation Dysregulation	Cell-mediated Rejection (CMR)	Chronic Rejection & AMR
αGal, Neu5Gc Pre-formed IgG/IgM Complement cascade	Non-Gal antibodies Complement activation Endothelial injury	Porcine vWF ↔ GPIIb/IIIa Tissue factor activation Platelet aggregation	T cell infiltration CD4/CD8 activation Cytokine storm	Alloantibody production Fibrosis/remodeling Endothelial activation
→ 3KO strategy	→ hCD46/55/59	→ hTBM/CD39/EPCR	→ Costim. blockade	→ hCD47/HO-1/PD-L1

**Genetic engineering of donor pigs is the central strategy to overcome each rejection barrier → enabling clinical xenotransplantation**

# 02

## Transgenic Pig Development - Current Status

### From Bench to Bedside: Clinical Milestone Timeline (2022–2025)

Jan 2022	<b>Univ. Maryland</b> First 10-GE pig heart into a living human (Faucette). Survived 60 days.
2022–23	<b>Brain-dead studies (NYU, Univ. Alabama)</b> Multiple kidney & heart xenotransplants in brain-dead recipients confirm functional feasibility.
Mar 2024	<b>MGH — eGenesis 69-GE pig kidney</b> Richard Slayman: first living-recipient pig kidney. Functioned 47 days. Compassionate use.
Nov 2024	<b>NYU Langone — Towana Looney</b> Longest surviving pig kidney recipient. Discharged with functioning xenograft.
2025	<b>Nature Medicine — Cardiac xenograft failure analysis</b> Systematic study: AMR confirmed as dominant failure mode. 'Strategies to overcome AMR are needed.'
Nov 2025	<b>United Therapeutics EXPAND Trial</b> First patient transplanted with UKidney (10-GE) under FDA IND Phase I approval.

## eGenesis: Genetic Engineering Strategy

Xenoantigen Knockouts	Human gene Knock-in	Anti-coagulation & Immuno-modulation
GGTA1 (αGal-KO) CMAH (Neu5Gc-KO) β4GalNT2-KO	CD46 (MCP) CD55 (DAF) CD59 hTBM, hEPCR hCD47, hHO-1	PERV-A, PERV-B, PERV-C (all 3 classes) CRISPR-Cas9 bulk edit
<b>Outcome:</b> Eliminates pre-formed Ab targets → Prevents HAR & AHXR	<b>Outcome:</b> Complement regulation Anticoagulation Immune evasion	<b>Outcome:</b> Biosafety: prevents retroviral transmission to human recipients

**NHP results: Avg 176 days survival | Longest >2 years in cynomolgus monkeys | Total: 69 genetic modifications**

## First Living-Recipient Pig Kidney Transplant (MGH, March 2024)

Patient: Richard Slayman, 62 (End-stage renal disease)	Key Outcomes & Lessons
<p><b>Donor pig:</b> eGenesis Yucatan miniature pig, 69-GE</p> <p><b>Surgery:</b> March 16, 2024, MGH (Kawai/Cosimi team)</p> <p><b>Functional endpoint:</b> Immediate urine production; normal GFR × 47 days</p> <p><b>Creatinine:</b> Fell from 3.5 → 1.4 mg/dL within 24h post-op</p> <p><b>Outcome:</b> Patient died May 11, 2024 (cardiac cause unrelated to xenograft)</p> <p><b>NHP preclinical:</b> Avg 176d, max &gt;2 years cynomolgus monkey</p> <p><i>Nat. Biotechnol. 2024</i></p>	<ul style="list-style-type: none"> <li>✓ Short-term xenograft function is achievable -proof of concept</li> <li>✓ 69-GE pig provides sufficient immunologic protection for &gt;4 weeks</li> <li>✓ PERV: not detected in any recipient blood samples</li> <li>⚠ Antibody-mediated rejection: emerging at 4–6 weeks</li> <li>⚠ Longer-term function limited: AMR, TMA still unsolved</li> <li>→ More sophisticated GE needed for durable function</li> </ul>

## United Therapeutics: UKidney — EXPAND Clinical Trial (2025)

First FDA-approved Phase I IND for xenotransplantation — November 3, 2025, NYU Langone

### UKidney Gene Edit Profile — 10 GE

#### KO: 4 knockouts

GGTA1, CMAH,  $\beta$ 4GalNT2 (3 xenoantigens)  
pGHR (porcine growth hormone receptor)

#### KI: 6 knock-ins

hCD46, hCD55 (complement)  
hTBM, hCD39 (anticoagulation)  
hCD47 (anti-phagocytosis)  
hHO-1 (cytoprotection)

### EXPAND Trial Design

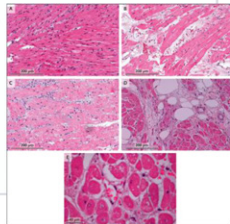
<b>Trial type:</b>	Phase I, safety & efficacy
<b>Sponsor:</b>	United Therapeutics
<b>Site:</b>	NYU Langone Medical Center
<b>Eligibility:</b>	ESRD on dialysis, no suitable living donor
<b>Primary endpoint:</b>	Safety at 12 months post-transplant
<b>Immunosuppression:</b>	Standard IS + anti-CD40 pathway
<b>First transplant:</b>	November 3, 2025

ClinicalTrials.gov EXPAND trial; Bhatt DL et al. Ann Thorac Surg 2024

## First Clinical Pig Heart Transplant

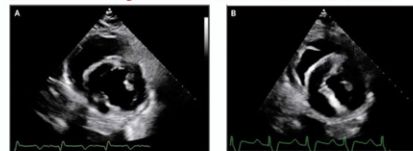
### First case in the World

**Patient:** David Bennett Sr., 57  
**Donor pig:** 10-GE (Revivicor/United Therapeutics)  
**Surgery:** January 7, 2022 (Griffith team, UMMC)  
**Gene edits:** 4 KOs + 6 KIs (no PERV inactivation)  
**IS protocol:** Anti-CD40L (Tegoprubart) + MMF + steroids  
**Cardiac function:** Good systolic function for ~30 days  
**Failure onset:** Day 20: progressive diastolic dysfunction  
**ECMO:** Day 50; patient died Day 60



### Second Case - Key Findings

**Patient:** Lawrence Faucette, 58 (UMMC, 2023)  
**Donor Pig:** 10-GE (United Therapeutics)  
**IS:** Anti-CD40L (Tegoprubart) costimulation blockade  
**Survival:** 40 days (diastolic failure onset ~Day 20)  
**Histology:** Capillary endothelial injury; interstitial edema; early fibrosis  
**Diagnosis:** AMR (antibody-mediated rejection)  
**Conclusion:** "Strategies to overcome AMR are needed"



Griffith BP et al. (Bennett case), NEJM 2022. (Faucette case), Nat Med 2025.

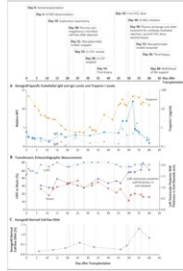
# First Clinical Pig Heart Transplant

## First Clinical Pig Heart Transplants: Lessons Learned

### Case 1: David Bennett Sr.

Jan 7, 2022 - UMMC (Griffith team)

- Day 0: Surgery**  
10-GE Revivicor pig; anti-CD40L + MMF
- Day 1-30: Good systolic function**  
No immediate rejection
- Day 20: Diastolic dysfunction**  
Progressive failure begins
- Day 50: ECMO support**  
Hemodynamic deterioration
- Day 60: Death**  
Cardiac failure



Griffith BP et al., NEJM 2022

### Case 2: Lawrence Faucette

Sep 22, 2023 - UMMC

- Day 0: Surgery**  
10-GE pig; anti-CD40L (Tegoprubart)
- Day 1-20: Stable function**  
Good cardiac output
- Day 20: Diastolic failure**  
AMR emerging
- Day 40: Death**  
AMR-driven failure
- Biopsy: Histology**  
Capillary injury; interstitial edema

Zhu Y et al., Nat. Med. 2025 - "Overcome AMR"

Griffith BP et al. (Bennett case), NEJM 2022; Zhu Y et al. (Faucette case), Nat Med 2025

# 03

## Our Research: Pig-to-NHP Xenotransplantation

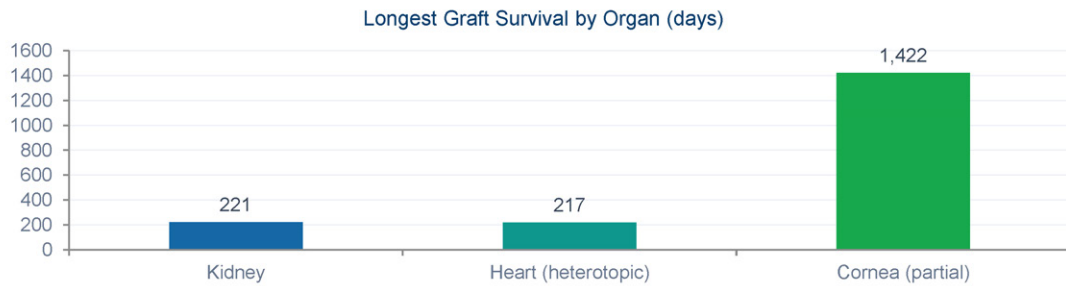
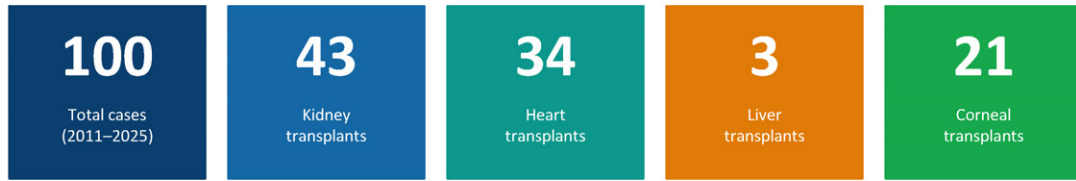
## Transgenic Pig in Korea

Institution	Pig Model	Genetic Modifications	Cases
Optipharm (Korea)	QKO Pig	GGTA1-KO + CMAH-KO + $\beta$ 4GalNT2-KO +B2M-KO CD39 + CD55 + CD46 + TBM (8 modifications)	8 models
NIAS (Korea)	Multiple-KI Pig	GGTA-KO + CMAH-KO + CD46+HO-1 + CD47 GGTA-KO + CMAH-KO + CD46+TBM + CD47 (5 modifications)	5 models

## Korea's Transgenic Pig Models — Current Status (~4–8 GE)

Gene	eGenesis (US)	UKidney (US)	Optipharm QKO-KI	NIAS 5GE
Total GE	69	10	7–8	6
GGTA1 KO	✓	✓	✓	✓
CMAH KO	✓	✓	✓	✓
$\beta$ 4GalNT2 KO	✓	✓	✓	—
hCD46	✓	✓	✓	✓
hCD55	✓	✓	✓	—
hTBM	✓	✓	✓	✓
hCD39	—	✓	✓	—
hHO-1	✓	✓	—	✓
hCD47	✓	✓	—	✓
PERV KO	✓ (59)	—	—	—
Stage	Clinical	Clinical	Preclinical	Preclinical

## 100 Pig-to-NHP Xenotransplantation Cases (2011–2025)



## Study Design & Methods

Donor Pigs	Recipients
<p>αGal-KO-based transgenic pigs                      Optipharm: QKO+CD39+CD55+CD46+TBM;                      NIAS: GTKO+CMAH+HO1+CD47</p>	<p>Cynomolgus monkeys (<i>Macaca fascicularis</i>).                      Rhesus monkey (<i>Macaca Mullata</i>)</p>
Immunosuppression	Monitoring & Endpoints
<p>Anti-CD154                      Rituximab (B-cell depletion)                      Anti-thymocyte globulin (ATG)                      Rapamycin / Tacrolimus                      Mycophenolate mofetil                      Steroids</p>	<p>Daily clinical assessment (scoring)                      Hematology (CBC)                      Serum chemistry                      Co-agulation                      Urinalysis                      Histopathology</p>

# 04

## Key Results - Kidney xenotransplantation

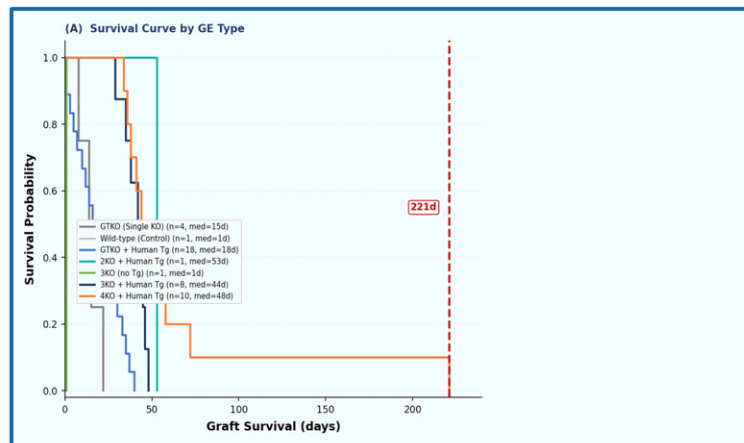
### Kidney Xenotransplantation Results (n=42)

221

days  
Longest graft survival  
(2022)

43

cases  
Total kidney  
xenotransplantations



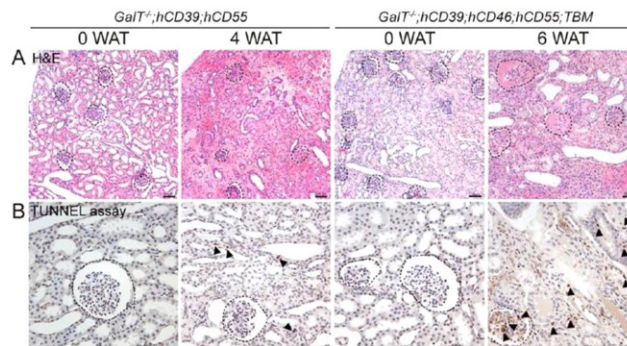
- Anti-CD154 costimulation blockade: key to survival extension
- Challenge: Thrombotic microangiopathy (coagulation dysregulation)

Date	Donor Type (GE Pig)	Recip. Sex	Immunosuppression	Contract. Response	Graft Survival (days)
2011.11.09	GTND	5.5 kg	ATG + R6 + Cb	—	2
2012.02.22	WT	5.5 kg	ATG + R6 + Cb	—	3
2012.01.31	ATND	5.5 kg	CVF + ATG + R6 + wCD354 + FcR306	—	26
2012.06.25	GTND	5.5 kg	CVF + ATG + R6 + wCD354 + FcR306	—	9
2014.04.14	GTND	4.9 kg	CVF + ATG + R6 + FcR306	POD 7	22
2017.03.16	GTND + CD39	5.4 kg	CVF + ATG + R6 + wCD354 + FcR306	POD 8	32
2017.08.22	GTND + CD46 + CD73	4.2 kg	CVF + ATG + R6 + wCD354 + FcR306	—	14
2017.07.21	GTND + CD39	5.3 kg	CVF + ATG + R6 + wCD354 + FcR306	POD 11	28
2018.03.26	GTND + CD46	4.5 kg	CVF + ATG + R6 + wCD354 + R6ge	—	12
2018.08.21	GTND + CD39	5.33 kg	CVF + ATG + R6 + wCD354 + R6ge	—	13
2018.12.03	GTND + CD46	4.4 kg	CVF + ATG + R6 + wCD354 + R6ge	—	7
2019.08.09	GTND + CD39 + CD55	4.12 kg	CVF + ATG + R6 + wCD354 + R6ge	POD 9	84
2018.11.22	GTND + CD39 + CD55	5.3 kg	CVF + ATG + R6 + wCD354 + R6ge	—	7
2020.12.17	GTND + CD39 + CD55	7.9 kg	CVF + ATG + R6 + wCD354 + R6ge	POD 11	86
2021.01.21	M0 + CD46 + T8M	3.5 kg	CVF + ATG + R6 + wCD354 + R6ge	POD 14	52
2021.03.11	M0	4 kg	CVF + ATG + R6 + wCD354 + R6ge	—	1
2021.01.25	GTND + CD39 + CD55	3.8 kg	CVF + ATG + R6 + wCD354 + R6ge	POD 14	82
2021.04.27	GTND + CD39 + CD55	3.3 kg	CVF + ATG + R6 + wCD354 + R6ge	—	8
2021.05.11	GTND + CD39 + CD55 + CD46 + T8M	3.2 kg	CVF + ATG + R6 + wCD354 + R6ge	POD 14	85
2021.06.17	M0 + CD46 + T8M	2.7 kg	CVF + ATG + R6 + wCD354 + R6ge	POD 14	49
2021.07.22	GTND + CD39 + CD55	3.8 kg	CVF + ATG + R6 + wCD354 + R6ge	—	43
2021.08.19	GTND + CD39 + CD55	4.4 kg	CVF + ATG + R6 + wCD354 + R6ge	POD 21	82
2021.10.14	M0 + CD39 + CD39	4.5 kg	CVF + ATG + R6 + wCD354 + R6ge	POD 21	36
2022.06.24	GTND + CD46 + T8M	3.07 kg	CVF + ATG + R6 + wCD354 + R6ge	POD 17	51
2022.08.05	GTND + CD46	4 kg	CVF + ATG + R6 + wCD354 + R6ge	POD 14	113
2022.08.19	GTND + CD39 + CD55	2.9 kg	CVF + ATG + R6 + wCD354 + R6ge	POD 76	80
2022.09.12	GTND + CD46 + T8M	2.9 kg	CVF + ATG + R6 + wCD354 + T8	POD 56	56
2022.10.29	M0 + CD39 + CD39	7.9 kg	CVF + ATG + R6 + wCD354 + T8	POD 75	203Max 221 days
2022.11.03	M0 + CD39 + CD39	2.6 kg	CVF + ATG + R6 + wCD354 + T8	POD 67	71
2022.07.26	M0 + CD39 + CD39	6 kg	CVF + ATG + R6 + wCD354 + T8	POD 14	29
2022.08.09	M0 + CD39 + CD39	5.7 kg	CVF + ATG + R6 + wCD354 + T8	POD 14	46
2022.08.23	M0	5.9 kg	CVF + ATG + R6 + wCD354 + T8	POD 14	36
2023.10.04	M0	7.5 kg	ATG + R6 + wCD354 + T8	POD 14	29
2023.12.27	M0 + CD46 + T8M	5.5 kg	CVF + ATG + R6 + wCD354 + T8	POD 14	29
2024.01.10	M0 + CD46 + T8M	6.4 kg	CVF + ATG + R6 + wCD354 + T8	POD 14	28
2024.01.24	M0 + CD46 + T8M	4.7 kg	CVF + ATG + R6 + wCD354 + T8	POD 21	72
2024.03.22	M0 + CD46 + T8M	5.7 kg	CrossM + ATG + R6 + P6G + 405 + T8	—	41
2024.03.27	M0 + CD46 + T8M	4.4 kg	CrossM + ATG + R6 + P6G + 405 + T8	—	34
2024.07.10	M0	4.3 kg	CVF + ATG + R6 + wCD354 + T8	POD 28	34
2024.07.10	M0 + CD46 + T8M + CD39 + CD55	5 kg	CVF + ATG + R6 + wCD354 + T8	POD 28	34
2024.10.21	M0 + CD46 + T8M + CD39 + CD55	4.9 kg	CrossM + ATG + R6 + P6G + 405 + T8	POD 40	44
2024.11.06	M0 + CD46 + T8M + CD39 + CD55	3.5 kg	CrossM + ATG + R6 + P6G + 405 + T8	POD 50	55

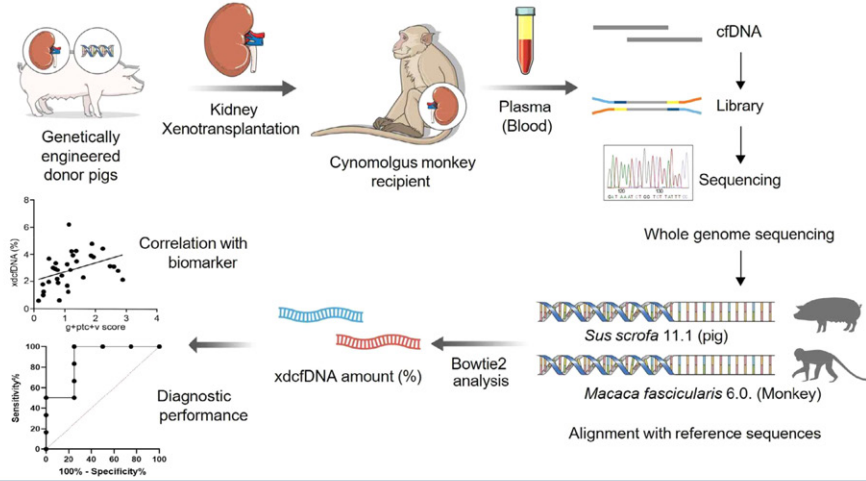
GTND only   
 GTND + Naupin Tg   
 M0 + Tg   
 M0 x Tg   
 M0 + Tg   
 Record survival

10 abbreviations: CVF = Janssen Jenifer; ATG = Polysciences; wCD354 = anti-CD354; R6ge = Regeneron; T8 = Tardigrade T8M; CrossM = CrossMatch; P6G 405 = anti-CD354; Regeneron; M0

## Kidney Xenograft Failure: Renal Histopathology



## xdcfDNA: Non-invasive Biomarker for Xenograft Rejection



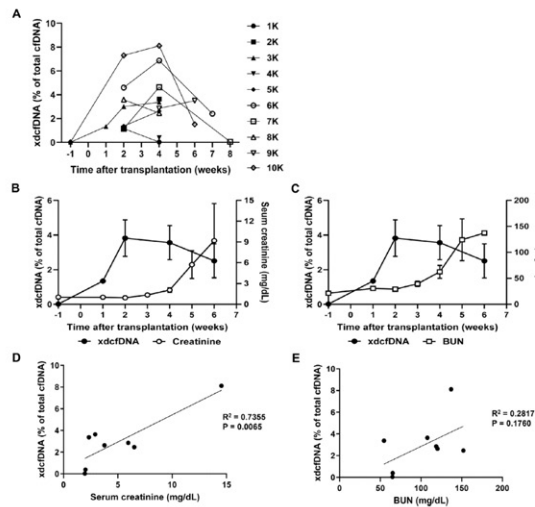
Porcine donor DNA circulates in recipient plasma → detected by WGS → mapped to *Sus scrofa* 11.1. Rise in xgcfDNA = early graft injury signal before creatinine/BUN elevation.

Han et al., *Xenotransplantation* 2025

## xdcfDNA: Kinetics & Diagnostic Performance for AMR Detection

### Key findings:

- ▶ xgcfDNA peaks at Wk 4–6 post-Tx
- ▶ Precedes creatinine/BUN rise
- ▶ AMR: AUC=1.000 at 2.545%
- ▶ 100% sensitivity & specificity
- ▶ Algorithm:
  - ≥1.25%→alert;
  - ≥2.545%→biopsy



Han et al., *Xenotransplantation* 2025

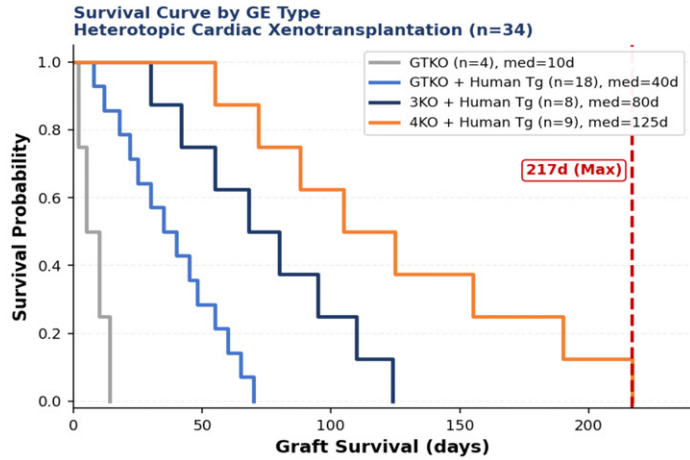
## Cardiac Xenotransplantation Results (n=34)

**217**

days  
Longest heterotopic  
heart graft survival

**34**

cases  
Total cardiac  
xenotransplantations



- PERV transmission: not detected in any recipient
- Transcriptome: heart failure mechanism differs between long/short-term survivors
- Refined immunosuppression (anti-CD154 + rapamycin) significantly extended survival

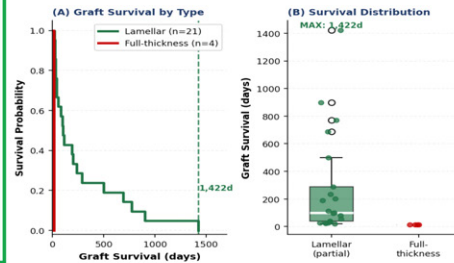
## Corneal Xenotransplantation Results (n=21)

**1,422**

days  
최장 각막 이식 생존  
(lamellar transplant)

Donor Pig	Recipient Monkey (Date of Surgery)	Graft Type	Initial Graft Opacity	Graft Survival	Size of Donor Cornea Punch	Size of Recipient Trephine
GTKO-CD46	272 (2021.07.23)	Partial thickness	14 d	28 d	7.0 mm	7.0 mm
	271 (2021.07.23)	Full thickness	14 d	28 d	7.5 mm	7.0 mm
GTKO-CD46+TBM	171 (2021.05.14)	Partial thickness	28 d	98 d	7.75 mm	7.25 mm
	172 (2021.05.14)	Full thickness	4 d	14 d	7.5 mm	7.5 mm
3KO	372 (2021.11.26)	Partial thickness	105 d	463 d (on-going)	7.0 mm	7.0 mm
	371 (2021.11.26)	Full thickness	16 d	21 d	7.5 mm	7.0 mm

**Corneal Xenotransplantation: Survival by Graft Type (n=25)**

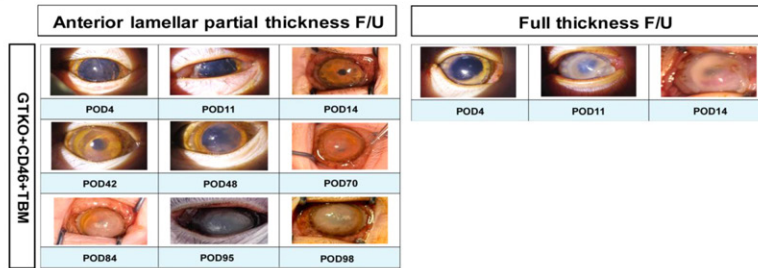


### Full-Thickness vs. Lamellar Corneal Xenograft

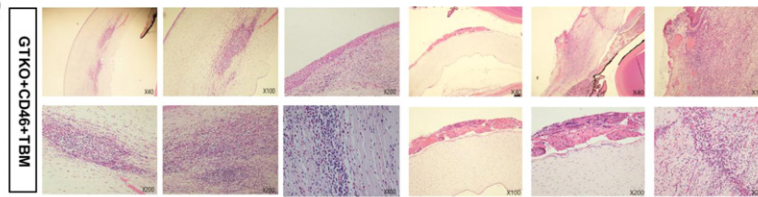
Parameter	Full-Thickness	Lamellar (Partial)
Immune response	Higher (MHC II exposure)	Lower
Graft survival	Shorter	Up to 1,422 days
Immunosuppression	Moderate-high	Minimal
Clinical recommendation	Higher risk	Preferred approach ✓

# Corneal Xenograft: Serial Slit-lamp Photos & Histopathology

(A)



(B)



## Partial Layer Corneal Xenotransplantation Results (2016–Present)

1,422d

Longest graft survival

>6mo

IXA clinical criterion MET

Table 5. Results of Partial Layer Corneal Transplantation from August 2016 to the Present

Date	Donor Type	Recipient	Graft Type	Immunosuppression	Graft Survival
2016.08.01	GTKO (5.8 kg)	5.9 kg	Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	100
2016.09.26	GTKO + CD46 (6.2 kg)		Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	234
2017.05.16	GTKO + CD46 (30 kg)		Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	202
2017.05.16	GTKO + CD46 (30 kg)		Partial thickness	DEXA + GENTA injection Steroid + Antibiotic eyedrop / Dexa + Genta injection	1422
2017.06.22	GTKO + CD46 + CD73 (4.4 kg)		Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	39
2017.06.22	GTKO + CD46 + CD73 (4.4 kg)		Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	39
2018.06.01	GTKO + CD46 (14.2 kg)	1.9 kg	Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	56
2019.02.27	GTKO + CD46 (5.6 kg)	3.38 kg	Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	772
2019.11.27	GTKO + CD46 (14.5 kg)	4.38 kg	Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	499
2020.04.08	GTKO + CD46 (4.1 kg)	3.6 kg	Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	21
2020.04.08	GTKO + CD46 (4.1 kg)	3.05 kg	Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	112
2021.03.12	TKO (14 kg)	4 kg	Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	26
2021.05.14	GTKO + CD46 + TBM (10.6 kg)	2.96 kg	Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	98
2021.07.23	GTKO + CD46 (18.5 kg)		Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	28
2021.11.26	GTKO + CD46 + TBM (4.3 kg)	2.5 kg	Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	899
2022.06.24	GTKO + CD46 + TBM (6.1 kg)		Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	689
2022.06.24	GTKO + CD46 (18 kg)		Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	28
2023.10.04	QKO + CD46 + TBM (9 kg)	2.46 kg	Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	289
2023.12.27	TKO + CD46 + TBM (7 kg)	3.19 kg	Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	23
2024.07.19	QKO + CD46 + TBM (7.4 kg)	3.6 kg	Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	>191
2024.11.06	QKO + CD55 + CD39 + CD46 + TBM (11 kg)	3.68 kg	Partial thickness	Steroid + Antibiotic eyedrop / Dexa + Genta injection	>81

GTKO, goat keratocyte; TKO, GTKO1/CMNH/βgal/RT1; QKO, GTKO1/CMNH/βgal/RT1; CD39, ectonucleoside triphosphate diphosphohydrolase-1; CD55, complement decay accelerating factor; CD 46, membrane cofactor protein; TBM, thrombospondin.

Table 5: Hwang SA et al., Transplant Proc. 57(8), 1674–1682, 2025

## Liver Xenotransplantation — Persistent Challenge (n=3)

<2

day  
Survival in all  
liver cases

### Major Barriers for Liver Xenotransplantation

- Severe coagulation dysregulation — pig liver produces species-incompatible coagulation factors
- Thrombotic microangiopathy develops within hours of reperfusion
- Acute rejection amplified by high portal blood flow
- Alternative: Bioartificial liver (BAL) — genetically modified pig hepatocytes in extracorporeal device
- Liver remains the most challenging organ for xenotransplantation globally

05

## Challenges & Future Strategy

## Remaining Challenges: Immunology & Coagulation

<p><b>Hyperacute Rejection (HAR)</b> <span style="float: right; background-color: green; color: white; padding: 2px 5px;">SOLVED</span></p> <p><math>\alpha</math>Gal-KO eliminates natural antibody-mediated HAR. Largely overcome in current models.</p>	<p><b>Acute Humoral Xenograft Rejection</b> <span style="float: right; background-color: red; color: white; padding: 2px 5px;">MAJOR BARRIER</span></p> <p>Non-Gal antibodies (CMAH, <math>\beta</math>4GalNT2) and complement activation persist. Primary cause of failure in kidney xenotransplantation.</p>
<p><b>Coagulation Dysregulation</b> <span style="float: right; background-color: red; color: white; padding: 2px 5px;">MAJOR BARRIER</span></p> <p>Species-incompatible coagulation factors drive thrombotic microangiopathy. CD39, TBM, CD73, anticoagulants partially mitigate.</p>	<p><b>Chronic Rejection</b> <span style="float: right; background-color: orange; color: white; padding: 2px 5px;">UNDER INVESTIGATION</span></p> <p>Long-term T cell-mediated rejection not yet fully characterized. Key hurdle for clinical durability.</p>

## Future Strategy: Toward Clinical Translation

- 1** **Next-Generation Transgenic Pigs**  
 10+ gene-edited pigs: additional xenoantigen knockouts (SLA class I reduction), **human immune checkpoint ligands (PD-L1, CD47)**, improved coagulation factors
- 2** **Refined Immunosuppression**  
 Novel costimulation blockade (anti-CD40L, belatacept), complement inhibitors (C1-INH, eculizumab), **tolerance induction via mixed chimerism**
- 3** **Novel Biomarkers**  
 Xenograft-derived cell-free DNA (xgcfDNA) for early non-invasive rejection monitoring — reduces biopsy need and enables timely intervention
- 4** **Clinical Trial Readiness (Korea)**  
 Build on 100+ NHP cases, partner with MFDS for IND application, **establish GMP-grade pig production**, initiate compassionate use → Phase I by 2027

## Korea Xenotransplantation Clinical Translation Roadmap

2011–2022	2023–2025	2025–2027	2028~
Preclinical Foundation	Scale-Up & Optimization	Compassionate Use & IND	Phase I Clinical Trial
100 NHP cases Max 221d kidney Max 1422d cornea	National funding XRC established New transgenic pigs Development	MFDS regulatory submission First human cases (bridge therapy)	IND approval Controlled trial 10–30 patients

## Conclusions

100+ pig-to-NHP xenotransplantations performed in Korea since 2011; kidney (221d), heart (217d), cornea (1,422d) demonstrate robust preclinical efficacy.

Lamellar corneal xenotransplantation with minimal immunosuppression is the most clinically mature application and nearest to clinical translation.

Multi-gene transgenic pigs (QKO + complement regulators + anticoagulants) are essential for overcoming AHXR and coagulation dysregulation.

Global clinical xenotransplantation has entered the Phase I trial era (FDA 2025). Korea is positioned to follow with national infrastructure.

Next steps: Next-gen pigs, refined immunosuppression, xgcfDNA validation, MFDS IND submission by 2027.

Thank you for your attention



# Processing Strategies to Improve Animal Protein Digestibility for Age-Specific Customization

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(Chungnam National University)

## Curriculum Vitae

- ▶ 2014~현재 충남대학교 동물자원생명과학과 교수
- ▶ 2013~2014 충남대학교, 서울대학교 박사후 연구원
- ▶ 2010~2013 충남대학교 축산학과 농학박사
- ▶ 2008~2010 충남대학교 축산학과 농학석사
- ▶ 2001~2008 충남대학교 동물자원생명과학과 농학사

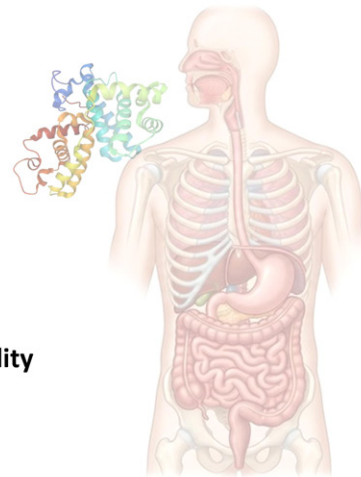


# Processing Strategies to Improve Animal Protein Digestibility for Age-Specific Customization

SAMOOEL JUNG  
CHUNGNAM NATIONAL UNIVERSITY

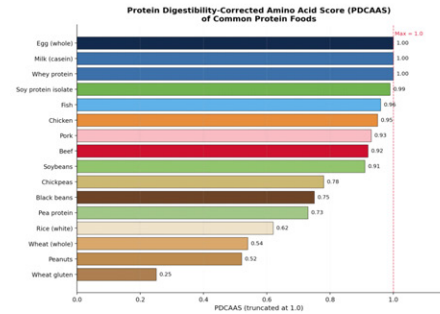
## Contents

1. Quality of Animal Food as an Ideal Protein Source
2. Physiological Barriers in Protein Digestion
3. Molecular Mechanisms: Denaturation & Oxidation
4. Clinical Implications of Infants & the Elderly
5. Advanced Processing Strategies for Improving Digestibility
6. Conclusion & Future Outlook



## Nutritional Advantages of Meat & Eggs

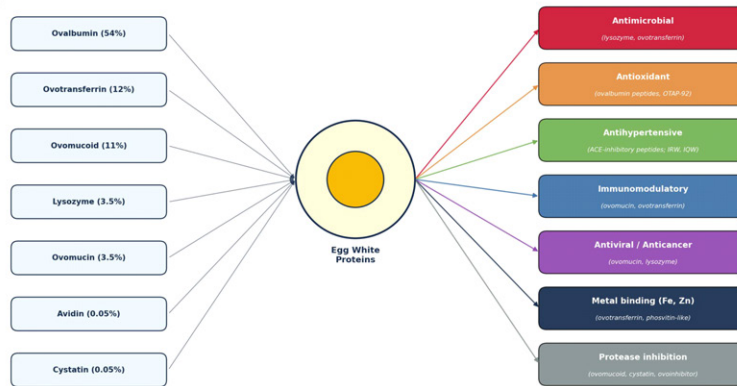
- **High quality, complete protein**
  - All essential amino acid & high BCAA (leucine, isoleucine, valine) contents
  - High bioavailability with high digestibility
  
- **Highly bioavailable micronutrients**
  - Meat: heme iron, zinc, Vit. B12
  - Eggs: choline, Vit. D, Vit. A
  
- **Bioactive peptides and non-protein nitrogen compounds**
  - Various peptides from protein digestion
  - Carnosine, anserine, creatine, taurine, and L-carnitine



## Nutritional Advantages of Meat & Eggs

### Bioactivity of egg white proteins

- Ovalbumin
- Ovotransferrin
- Ovomuroid
- Lysozyme
- Ovomucin
- Avidin
- Cystatin



Native proteins → GI digestion / enzymatic hydrolysis → Bioactive peptides → Systemic health effects

Infant Gastrointestinal Track: Immature Physiology

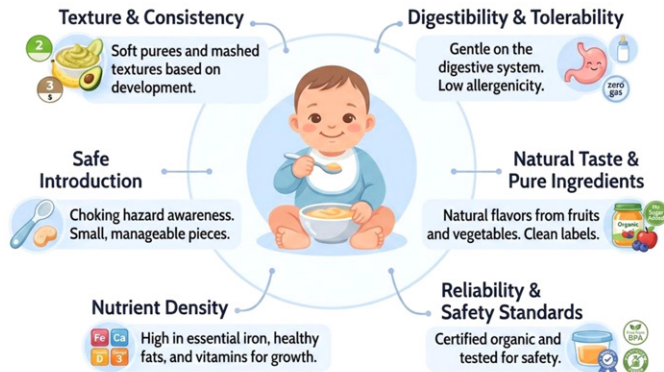
**Digestive Physiology in the Infant**

- Gastric Acid Secretion ↓**  
Reduced initial protein denaturation
- Pepsin Activity ↓**  
Slower cleavage of large proteins  
Less complete protein pre-digestion
- Gastric Emptying ↑**  
Faster movement to small intestine, reduced breakdown time
- Pancreatic Enzyme Secretion ↓**  
Lower levels of trypsin, chymotrypsin, and other proteases
- Intestinal Brush Border Activity ↓**  
Lower disaccharidase activity and other enzyme processes

**Result:**

- ⚠ Overall protein digestibility reduced in immature GI tract.
- ⚠ Requires tailored food design and optimized processing for absorption.

Infant-Friendly Food Requirements



Senescent Gastrointestinal Track: Age-related Decline

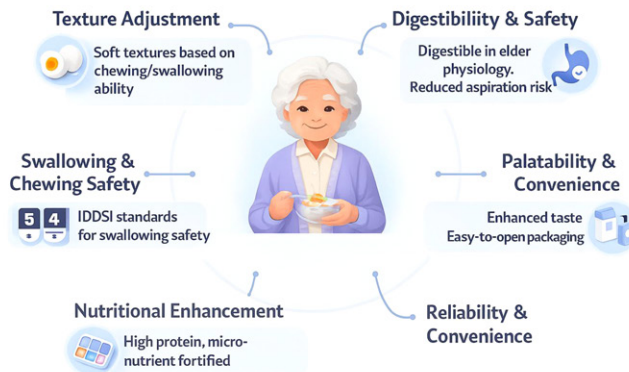
**Digestive Physiology in the Elderly**

- Gastric Acid Secretion ↓**  
Reduced protein denaturation
- Pepsin Activity ↓**  
Lower cleavage of large proteins  
More undigested proteins entering intestine
- Gastric Emptying ↓**  
Slower movement to small intestine
- Enzyme Secretion ↓**  
(trypsin, chymotrypsin, pancreatic enzymes)
- Intestinal Absorption Efficiency ↓**  
Lower amino acid uptake

**Result:**

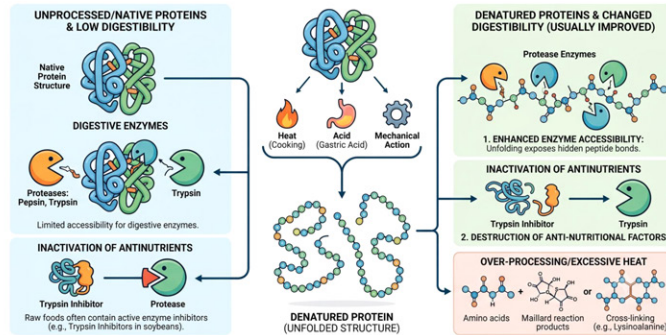
- ⚠ Overall protein digestibility significantly reduced
- ⚠ Risk of sarcopenia ↑, immune decline

Elderly-Friendly Food Requirements



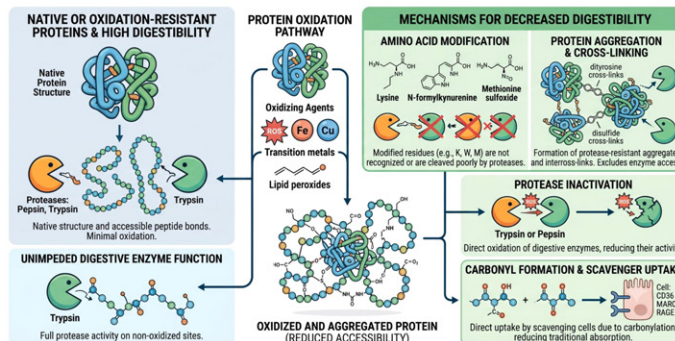
## Double-Edged Sword of Protein Denaturation

- **Protein digestibility increased**
  - Increase in protease accessibility by exposing buried cleaving sites with unfolding
  - Inactivation of protease inhibitors
- **Protein digestibility decreased**
  - Decreased in protease accessibility by aggregations (physical or non-covalent clumping) of proteins
  - Unrecognition of protease by chemical side reactions (covalent cross-linking or Maillard reaction) of proteins

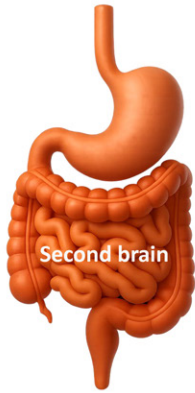


## Detrimental Impact of Protein Oxidation

- **Structural collapse and aggregation**
  - Formation of protein-carbonyl compounds by chemical oxidation
- **Steric hindrance**
  - Oxidized proteins to re-collapse into highly compact, rigid polymers
  - Blocking protease access to binding pockets



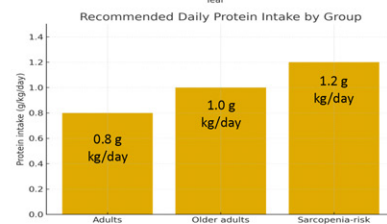
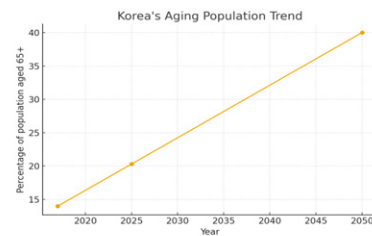
Consequences of Poor Proteolysis in Infants



- **Growth faltering and nutritional deficiencies**
  - Amino acid deficiencies: Decrease in protein synthesis
  - Stunted growth: Delayed physical growth, poor weigh gain
  
- **Gastrointestinal distress and discomfort**
  - Fermentation and gas: Fermentation of undigested protein in the large intestine (severe abdominal discomfort with the production of excess gas)
  - Altered stool patterns: Leading to diarrhea or constipation by causing osmotic imbalances

Consequences of Poor Proteolysis in the Elderly

- **Acceleration of sarcopenia and frailty**
  - Blunted muscle synthesis: Low absorption of essential amino acids
  - Increased frailty: Decrease in muscle mass
  
- **Impaired immune function and wound healing**
  - Delayed healing: Decrease in repairing skin barrier matrices
  - Higher infection risk: Low cellular immunity
  
- **Colonic fermentation and gut discomfort**
  - Toxic metabolites generated in the large intestine

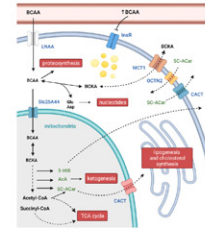


# Advanced Processing Strategies for Improving Digestibility

## Materials and Methods

### Samples

- Beef for infant complementary foods
- Egg white for elderly-friendly foods



### Static in-vitro digestion model

- INFOGEST protocol: young adult, infants, the elderly
- Digestibility: < 3 kDa via cut-off filter

**nutrac** protocols **PROTOCOL**

**INFOGEST static in vitro simulation of gastrointestinal food digestion**

Andri Brodbeck<sup>1</sup>, Lutz Egger<sup>2</sup>, Marie Abminger<sup>3</sup>, Paula Ahlke<sup>4</sup>, Ricardo Assunção<sup>5</sup>, Sonja Ballmann<sup>6</sup>, Tigran Bittel<sup>7</sup>, Claire Bruchler-Lacand<sup>8</sup>, Rachel Brunsen<sup>9</sup>, Frederic Casarin<sup>10</sup>, Alfonso Clemente<sup>11</sup>, Milena Corredig<sup>12</sup>, Didier Dupont<sup>13</sup>, Claire Dufour<sup>14</sup>, Catherine Edwards<sup>15</sup>, Matt Goding<sup>16</sup>, Sajeel Karkhanavala<sup>17</sup>, Boris Krichen<sup>18</sup>, Steven La Feunteun<sup>19</sup>, Ulf Lorenzen<sup>20</sup>, Adam Macfarlane<sup>21</sup>, Alan R. Mackie<sup>22</sup>, Carla Martinez<sup>23</sup>, Sebastian Merra<sup>24</sup>, David Julian McClements<sup>25</sup>, Christa Muehle<sup>26</sup>, Maria Mulet<sup>27</sup>, Risto Partanen<sup>28</sup>, Claudio N. Sant'Ana<sup>29,30</sup>, Isabelle Souchoir<sup>31</sup>, B. Paul Singh<sup>32</sup>, Gergely Varga<sup>33</sup>, Martin S. J. Wickham<sup>34</sup>, Werner Watznicher<sup>35</sup> and Isabella Weis<sup>36</sup>

Developing a mechanistic understanding of the impact of food structure and composition on human health has increasingly become a challenge. In the upper gastrointestinal tract, these components have to be broken down into different conditions that often have very little physiological relevance, and this involves the meaningful combination of results. The standardized protocol presented here is based on an international consensus developed by the INFOGEST network. The method is designed to be used with standard laboratory equipment and requires limited resources to reproduce a wide range of researchers to adopt it. It is a static digestion method that uses constant rates and time to digest foods and is consistent for each step of digestion. This makes the method simple to use but not suitable for assessing digestion kinetics. Using this method, food samples are subjected to sequential and sequential digestion with parameters such as substrate, enzymes, time, substrate pH and time of digestion are based on available physiological data. This standardised and detailed digestion method (INFOGEST 2.0) is available for download with the original method, such as the inclusion of the oral phase and the use of gastric juice. The method can be used to assess the indicators resulting from digestion of foods by analyzing the digestion products (e.g., peptides/amino acids, fatty acids, simple sugars) and evaluating the release of micronutrients from the food matrix. The whole protocol can be completed in 7-8, including 5 if required for the determination of enzyme activities.

Step	Protocol
1	Perform enzyme activity and bile assays
2	Prepare SSF and SSF stock solutions
4	Perform pH test adjustment experiment
7-12	Mix Food with SSF (1:1, wet/wet)
13	Include CaCl <sub>2</sub> (1.5 mM in SSF)
14	Add salivary amylase, if necessary (75 U/mL)
15, 16	Inoculate while mixing (2 min, 37 °C, pH 7)
17, 18	Mix oral Inocul with SSF (1:1 (wet/wet))
19	Include CaCl <sub>2</sub> (0.15 mM in SSF)
20, 21	Add pepsin, gastric lipase (2,000, 60 U/mL)
22-24	Inoculate while mixing (2 h, 37 °C, pH 3.0)
25, 26	Mix gastric chyme with SSF (1:1 (wet/wet))
27	Include bile (10 mM bile salts)
28	Include CaCl <sub>2</sub> (0.6 mM in SSF)
29	Add pancreatin (trypan activity 100 U/mL)
30-32	Inoculate while mixing (2 h, 37 °C, pH 7.0)

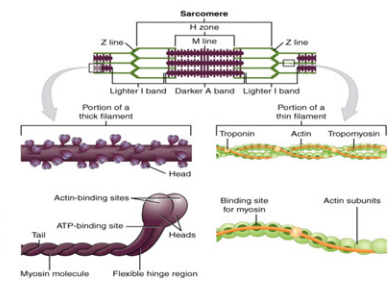
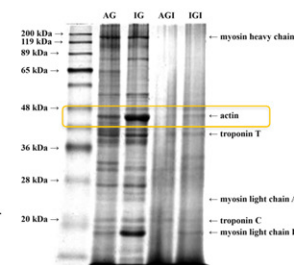
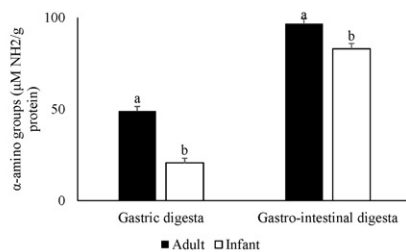
Sampling procedure and sample treatment (Table 1)

### Protein structure

- Circular dichroism analysis
- Surface hydrophobicity, Fluorescence intensity

# Advanced Processing Strategies for Improving Digestibility

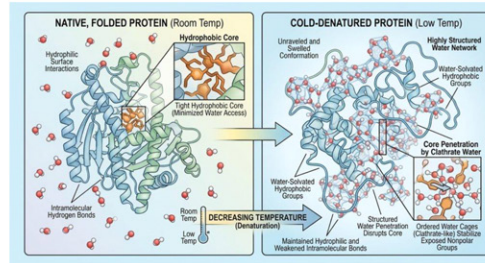
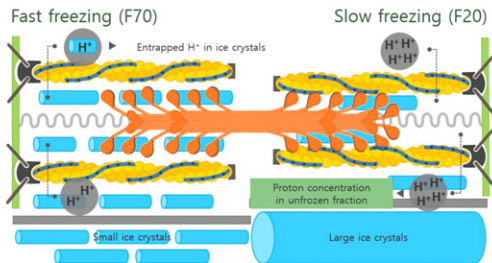
## Beef Protein Digestion: Adult vs. Infant



### Results

- Beef protein digestibility was lower in both the gastric and gastrointestinal phases of the infant simulated digestion model than in the adult model.
- Actin is the main protein with **digestive resistance** because the trypsin or chymotrypsin can not cleave **F-actin** since the cleaving sites are buried by the actin-actin interaction (Hozumi, The Journal of Biochemistry 104, 285).

Beef Protein Digestion: Freezing-then-aging

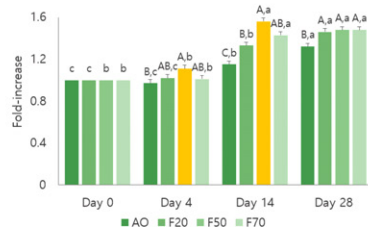


Hypothesis

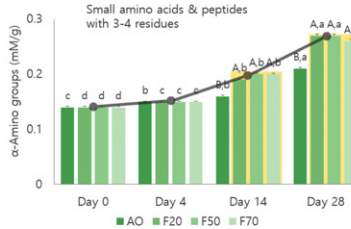
- During the freezing process, the ice crystal formation results in the physical damage of the lysosome and release of cathepsin. Cold denaturation of muscle protein may change the behavior of protein digestibility.
- During the aging of beef, the degradation of muscle protein may improve the digestibility.

Beef Protein Digestion: Freezing-then-aging

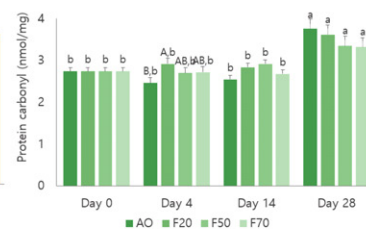
Cathepsin B activity



α-Amino group content



Protein oxidation

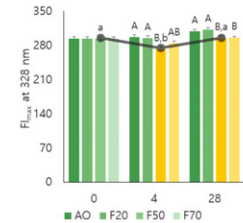
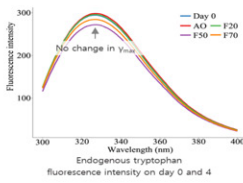


Results

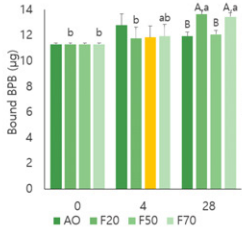
- Cathepsin B activity was increased in the frozen-thawed beef, especially in F50 at day 14.
- Degradation of muscle proteins was increased in the frozen-thawed beef.
- Protein oxidation was increased after the 28-days aging process. However, no significant effect of freezing on the protein oxidation was found.

Beef Protein Digestion: Freezing-then-aging

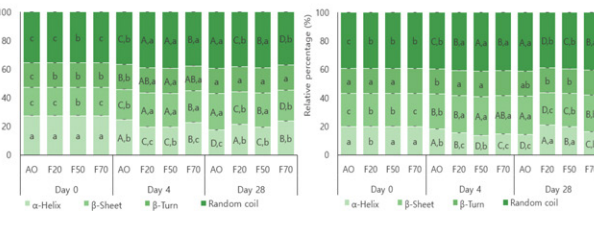
Fluorescence intensity



Surface hydrophobicity



Secondary structure of myosin and actin fractions

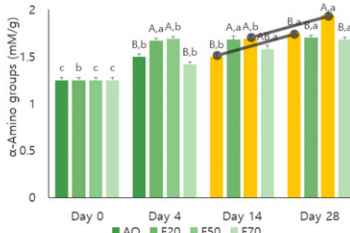


Results

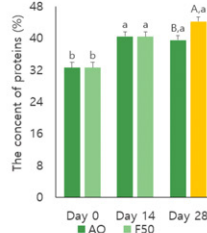
- Fluorescence intensity of F50 was low at day 14 and 28. However, the surface hydrophobicity showed no consistent results.
- In myosin and actin, denaturation and renaturation properties were observed on day 14 and 28, respectively, in frozen-thawed beef except for F50 myosin.

Beef Protein Digestion: Freezing-then-aging

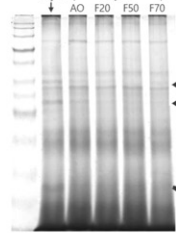
α-Amino groups of digesta



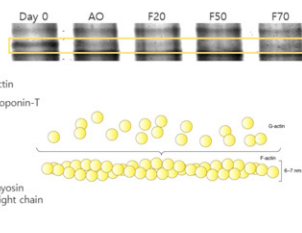
Proteins <3 kDa



SDS-PAGE



Actin band

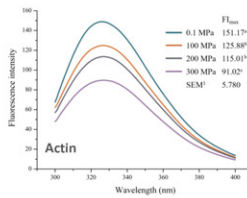
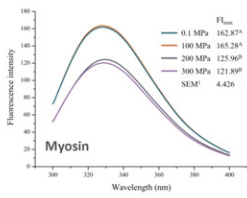


Results

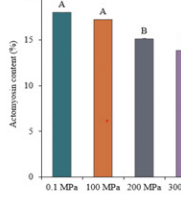
- After aging, the **actin** band disappeared in the freezing-then-aging beef.
- Aging and the pre-freezing process resulted in an increase in beef protein digestibility.
- F50 (frozen at -50°C) with 28 days of aging showed the highest protein digestibility.

Beef Protein Digestion: High Hydrostatic Pressure

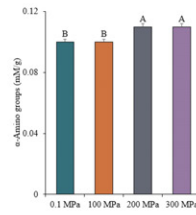
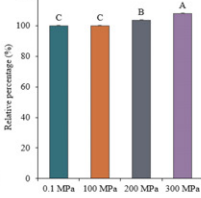
Fluorescence intensity



Beef Properties



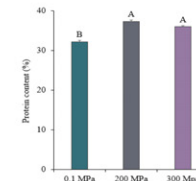
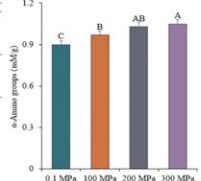
Beef Properties



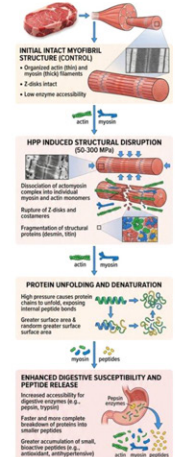
Secondary structure

Treatment	α-Helix	β-Sheet	β-Turn	Random coil
Myosin	0.130 <sup>a</sup>	14.68 <sup>a</sup>	17.72 <sup>a</sup>	64.47 <sup>a</sup>
100 MPa	14.08 <sup>a</sup>	17.18 <sup>a</sup>	15.91 <sup>a</sup>	52.82 <sup>a</sup>
200 MPa	12.36 <sup>a</sup>	28.21 <sup>a</sup>	15.90 <sup>a</sup>	43.29 <sup>a</sup>
300 MPa	12.50 <sup>a</sup>	39.03 <sup>a</sup>	15.80 <sup>a</sup>	32.19 <sup>a</sup>
SEM	0.211	0.977	0.689	0.178
Actin	0.132 <sup>a</sup>	12.50 <sup>a</sup>	40.17 <sup>a</sup>	47.19 <sup>a</sup>
100 MPa	11.24 <sup>a</sup>	40.90 <sup>a</sup>	15.59	31.91 <sup>a</sup>
200 MPa	10.53 <sup>a</sup>	43.43 <sup>a</sup>	15.37	30.24 <sup>a</sup>
300 MPa	10.20 <sup>a</sup>	41.85 <sup>a</sup>	15.30	30.26 <sup>a</sup>
SEM	0.209	0.821	0.683	0.141

Protein digestibility

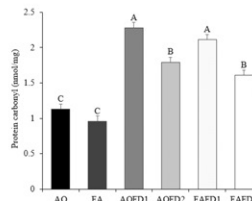


PHYSIOLOGICAL FRAGMENTATION OF MYOFIBRILS IN RAW MEAT BY HIGH-PRESSURE PROCESSING (50-300 MPa)

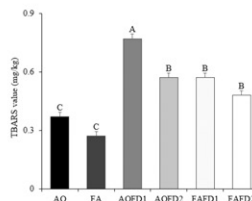


Beef Protein Digestion: Freeze-drying with room or low temperature

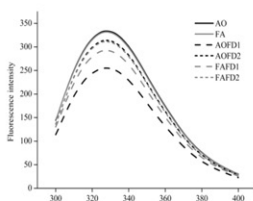
Protein oxidation



Lipid oxidation



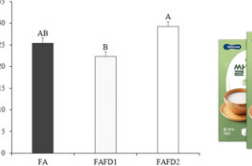
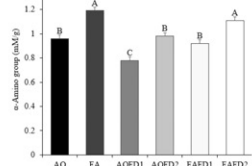
Fluorescence intensity



Secondary structure

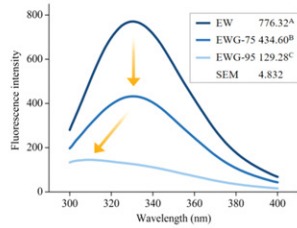
Treatment	α-Helix	β-Sheet	β-Turn	Random coil
Myosin	AO 17.15 <sup>c</sup>	24.67 <sup>a</sup>	17.54	40.60 <sup>a</sup>
FA	21.83 <sup>b</sup>	22.21 <sup>b</sup>	17.40	38.55 <sup>b</sup>
AOFD1	17.67 <sup>c</sup>	24.74 <sup>a</sup>	17.77	39.82 <sup>a</sup>
AOFD2	21.09 <sup>b</sup>	22.71 <sup>b</sup>	17.45	38.76 <sup>b</sup>
FAFD1	22.38 <sup>b</sup>	22.29 <sup>b</sup>	17.44	37.89 <sup>b</sup>
FAFD2	25.55 <sup>a</sup>	20.66 <sup>c</sup>	17.28	36.51 <sup>c</sup>
SEM <sup>c</sup>	0.335	0.205	0.110	0.197
Actin	AO 13.40 <sup>b</sup>	27.33 <sup>b</sup>	17.41 <sup>ab</sup>	41.86 <sup>a</sup>
FA	15.04 <sup>a</sup>	26.34 <sup>b</sup>	17.54 <sup>ab</sup>	41.08 <sup>ab</sup>
AOFD1	12.23 <sup>b</sup>	28.60 <sup>a</sup>	17.47 <sup>ab</sup>	41.74 <sup>a</sup>
AOFD2	13.60 <sup>b</sup>	27.57 <sup>b</sup>	17.52 <sup>ab</sup>	41.30 <sup>ab</sup>
FAFD1	12.88 <sup>c</sup>	27.76 <sup>c</sup>	17.79 <sup>a</sup>	41.57 <sup>ab</sup>
FAFD2	15.50 <sup>a</sup>	26.36 <sup>b</sup>	17.56 <sup>ab</sup>	40.58 <sup>b</sup>
SEM <sup>c</sup>	0.101	0.169	0.064	0.233

Protein digestibility

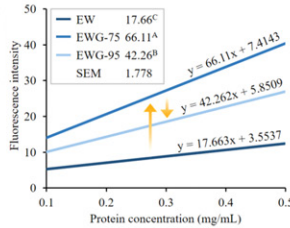


Egg White Protein Digestion: Different heating temperature

Fluorescence intensity



Surface hydrophobicity



Secondary structural components

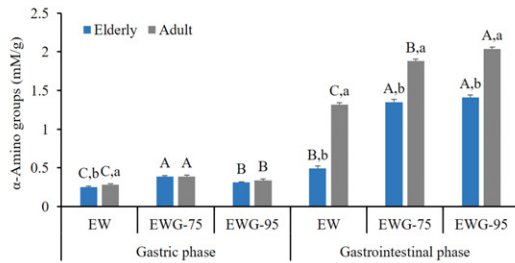
Treatment	α-Helix	β-Sheet	β-Turn	Random coil
EW	41.81 <sup>A</sup>	14.11 <sup>B</sup>	17.60 <sup>B</sup>	26.49 <sup>A</sup>
EWG-75	42.15 <sup>A</sup>	13.13 <sup>B</sup>	16.93 <sup>C</sup>	27.80 <sup>A</sup>
EWG-95	30.57 <sup>B</sup>	25.85 <sup>A</sup>	19.53 <sup>A</sup>	24.05 <sup>B</sup>
SEM	0.870	0.681	0.127	0.633

Results

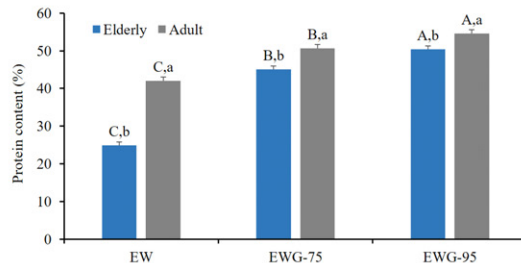
- EWG-95 showed the lowest fluorescence intensity with a blue shift.
- The surface hydrophobicity was increased in EWG-75 and 95 compared to EW. However, EWG-95 showed lower surface hydrophobicity than EWG-75.
- EWG-95 consisted of lower α-helix and higher β-sheet content compared to EW and EWG-75.

Egg White Protein Digestion: Different heating temperature

α-Amino groups of digesta



Contents of protein < 3 kDa

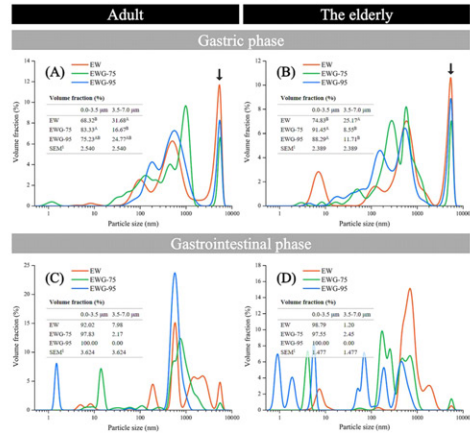


Results

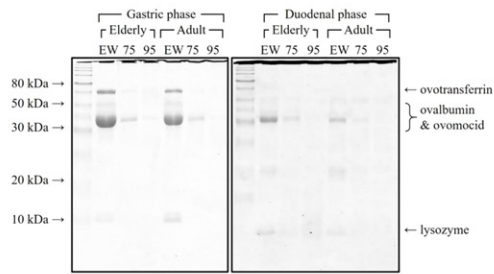
- Amino group contents in the gastrointestinal phase were higher in the adult model than in the elderly model.
- Protein digestibility increased in EWG compared to EW.
- EWG-95 had higher protein digestibility than EWG-75.

Egg White Protein Digestion: Different heating temperature

Particle size distribution of digesta



SDS-PAGE of digesta



Results

- Disruption of native EWPs including protease inhibitor, may play a more significant role in enhancing protein digestibility despite severe aggregation.

Conclusion & Future Outlook

Conclusion

- Animal food proteins (meat and eggs) possess excellent initial nutritional profiles, but their dense, native macromolecular networks limit actual bioaccessibility in underdeveloped or declining gastrointestinal tracts.
- Optimizing structural processing conditions can significantly enhance *in vitro* protein digestibility and kinetics.
- Animal foods provide maximum nutritional value when custom-tailored to the physiological needs of specific target consumers.

Future Outlook

- *In vivo* translation and clinical dietary trials
- Comprehensive peptidomic mapping and bioactivity tracking
- Industrial scale-up and development of age-specific medical foods



Thank you

## Appendix

### List of Published Core Research (Our Publications)

- Low protein digestibility of beef puree in infant in vitro digestion model. 2019. Food Sci. Ani. Resour. 39:1000-1007.
- Improvement of meat protein digestibility in infants and the elderly. 2021. Food Chem. 356, 129707.
- Freezing-then-aging treatment improved the protein digestibility of beef in an in vitro infant digestion model. 2021. Food Chem. 350, 129224.
- Changes in beef protein digestibility in an in vitro infant digestion model with prefreezing temperatures and aging periods. 2023. Heliyon, 9, e15611.
- High-pressure processing of beef increased the in vitro protein digestibility in an infant digestion model. 2023. Meat Sci. 205, 109318.
- Characterization of peptides released from frozen-then-aged beef after digestion in an in vitro infant gastrointestinal model. 2024. Meat Sci. 212, 109468.
- Heat-induced gelation of egg white proteins depending on heating temperature: Insights into protein structure and digestive behaviors in the elderly in vitro digestion model. 2024. Int. J. Bio. Macromol. 262, 130053.

# Heat Stress and Marbling Development in Beef Cattle

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Kim, Jongkyoo

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## Curriculum Vitae

- ▶ 2026~현재 미국 Michigan State University, Associate Professor
- ▶ 2020~2026 미국 Michigan State University, Assistant Professor
- ▶ 2018~2019 미국 Texas Tech University, 박사후 연구원
- ▶ 2013~2017 미국 Texas Tech University, Muscle Biology, 박사
- ▶ 2010~2012 충북대학교 대학원 반추영양학 석사
- ▶ 2002~2009 충북대학교 축산학과 농학사



# Heat Stress and Marbling Development in Beef Cattle

Jongkyoo Kim

Department of Animal Science, Department of Food Science and Human Nutrition,  
Michigan State University, East Lansing, MI, USA

The effect of heat stress on skeletal muscle depends on its intensity and duration. Short-term moderate exposure can be adaptive. It induces heat shock proteins, increases satellite cell proliferation through HSP27, and maintains protein synthesis via the mTOR pathway. Beyond a protective threshold, the response becomes catabolic, with reactive oxygen species accumulation, mitochondrial dysfunction, and increased protein degradation. Beef-on-Dairy systems are of particular interest because they expose animals during two windows: late gestation and an extended finishing period. We exposed Holstein dams to heat stress or active cooling during the final 54 d of gestation. In utero heat stress lowered offspring birth weight and average daily gain and shifted the semitendinosus toward a Type I oxidative phenotype with higher heat shock protein abundance and satellite cell activity. In feedlot steers, 28 d of heat stress reduced dry matter intake, adjusted final body weight ( $p = 0.013$ ), and hot carcass weight ( $p = 0.038$ ), with no change in backfat, ribeye area, or KPH fat. Marbling did not increase. Energy was partitioned toward subcutaneous and visceral fat, and muscle shifted to an oxidative metabolism that draws on adjacent lipid. Heat stress, aggressive stacked implants, and  $\beta$ -adrenergic agonists each divert nutrients from intramuscular adipogenesis, and their effects on marbling are additive. Dietary fat supplementation may help preserve marbling by maintaining intramuscular and intramyocellular lipid reservoirs. These data point to nutrition and management strategies that extend thermal tolerance and protect carcass quality during heat stress.

**Keywords :** heat stress, skeletal muscle, marbling, intramyocellular lipid, fetal programming



# From Waste to Resources: Multi-Pathway Approaches for Livestock Waste Resource Recovery and Greenhouse Gas Mitigation

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## Curriculum Vitae

- ▶ 2026~현재 전남대학교 동물자원학부 조교수
- ▶ 2025~2025 국립축산과학원 스마트축산환경과 농업연구관
- ▶ 2022~2025 한양대학교 자원환경공학과 공학박사
- ▶ 2018~2022 세종대학교 환경에너지융합학과 공학박사(수료)
- ▶ 2015~2018 전남대학교 동물공학과 농학석사
- ▶ 2014~2024 국립축산과학원 축산환경과 농업연구사
- ▶ 2008~2015 전남대학교 동물자원학부 농학사





# Sustainable Livestock Waste Valorization through Intergrated Conversion Process

□ □ □ □ □ □ □ □

Department of Animal Science  
Chonnam National University

Dong-Jun Lee, Ph. D.

## Education & Research Careers

2

### Work Experience

#### Senior researcher, NIAS, RDA (2025.01.~2025.12.)

- Energy recovery from livestock manure (BSFL)
- Biochar production and application

#### Reseracher, National Institute of Animal Science (NIAS), RDA (2014.08.~2024.12.)

- Thermochemical conversion of livestock manure for energy recovery (Pyrolysis, Solid fuel)
- Biological treatment of livestock manure (Composting & Liquid fertilization)

### Research area

#### Livestock manure management and resource recovery

- Thermochemical conversion (pyrolysis, solid fuel production)
- Biochar production & utilization
- CO<sub>2</sub> utilization
- Biofuel (Biodiesel)

### Project

#### Institutional research projects on livestock mnuare treatment

- Quality enhancement of cattle manure solid fuel ~ for ash derived from combustion of cattle manure solid fuel + 10 projects (RDA)
- Changes in livestock manure characteristics during resource recovery facility operation (24, KOSPO)
- Development of portable measuring system for compost maturity using gas concentration measurement techniques (21-22, IPET)
- Monitoring of water evaporation from liquid fertilizer storage tanks in swine farms (19, KPPA)

### Patent & transfer

#### 11 Patents, 3 case of design trasfer

- Method and device for calculating moisture content to achieve target lower heating value ('24)
- Method and apparatus for predicting calorific value of cattle manure solid fuel using compositional information of cattle manure ('24)
- Method and apparatus for calculating unit emission factors of livestock manure ('24)

### Activities

#### Advisory activities in livestock environmental field

- Establishment of agro-livestock circular system activation plan ('25~current)
- Joint planning committee work for livestock manure solid fuel ('24~'25)
- Review and advisory committee member for livestock environment status survey ('22~current)
- Livestock manure treatment facility supply project ('19~current)

## Research motivation

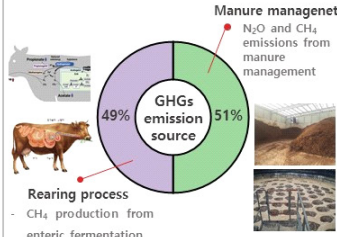
### Changes in the Livestock environment

#### Livestock waste and Environmental burden



- > Livestock manure generation
  - 50.8 million tons in 2023
- > Current status
  - 84.5% (Compost 72.7%+Liquid 11.8%)

#### Livestock-derived GHGs emissions



- > Nutrient loading \* ( )은 저장량
  - Nitrogen 301 (169), Phosphorus 61 thousand (23)
- > GHGs emission('21)
  - Manure management: 5.4 million tons CO<sub>2</sub>-eq (25%)



#### Waste reduction & management

- Thermochemical process (Pyrolysis, Solkates)
- Waste upcycling (Insect biomass)

#### Reduction of carbon emission

- Carbon sequestration (biochar)
- Carbon-to-utilization

## Research motivation

Combustion (Heat): over 1000 °C

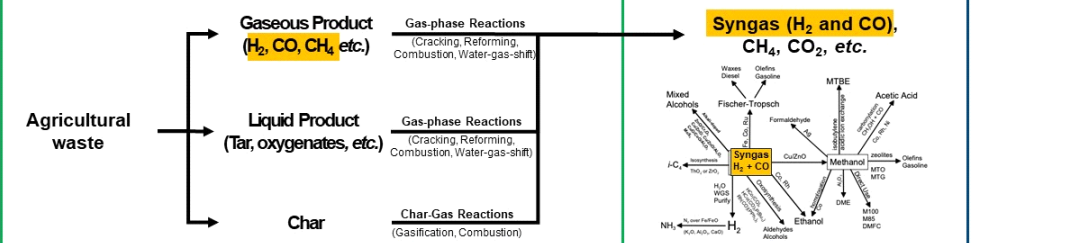
Complete oxidation

Gasification: 700 – 1500 °C

Partial oxidants (O<sub>2</sub>, air, steam, etc.)

Pyrolysis: 300 – 700 °C

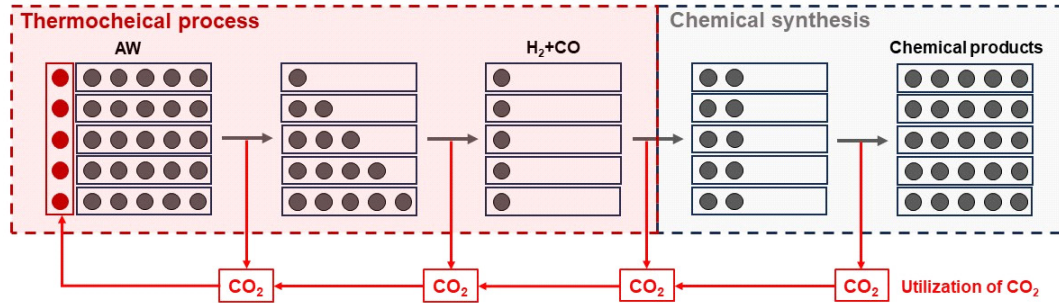
Absence of oxidant



- ✓ (Gasification) Energy intensive process
- ✓ (Pyrolysis) Intermediate step of gasification → lower energy input
- ✓ **Research objective : Pyrolysis temperature range + strategies to increase syngas yield**

## Research motivation

### Overall process for synthesis of chemicals and fuels



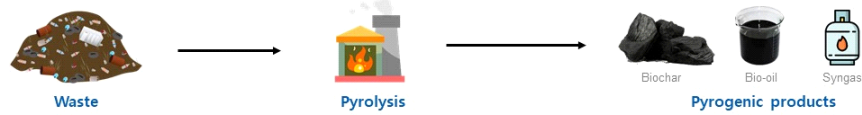
### Agricultural waste (Livestock waste&agricultural plastic waste)



## Pyrolysis

### CO<sub>2</sub>-assisted pyrolysis

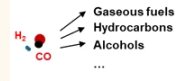
**Pyrolysis?** A thermochemical decomposition process occurring in the absence of oxygen, where carbonaceous materials are heated to high temperatures to produce biochar, bio-oil, and syngas



**01 Main target products: bio-oil**  
- Heterogeneous ⇒ Separation & purification required

#### Main target: syngas

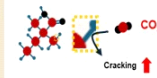
- A platform chemical
- Easy application



**02 Toxic chemical generation**  
- Low thermal cracking

#### Suppression of pollutant formation

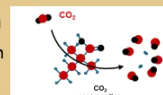
- Blocking the pathway to form PAHs
- Enhancement of thermal cracking



**03 Carbon dioxide emission**  
- CO<sub>2</sub> generation during the process

#### Carbon dioxide consumption

- Reduction of carbon emission
- Carbon conservation

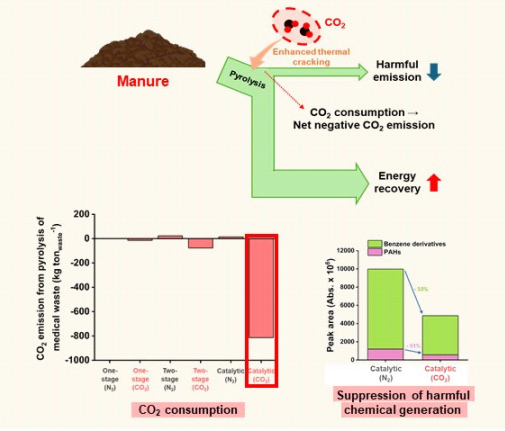


# Pyrolysis

## CO<sub>2</sub>-assisted pyrolysis

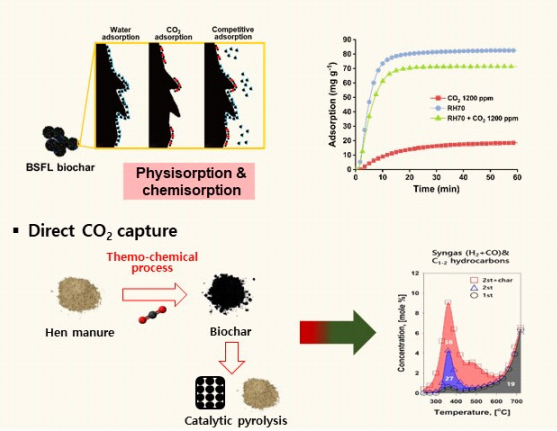
### Carbon-negative waste management

- Reduction of CO<sub>2</sub> emission during processes



### Biochar application

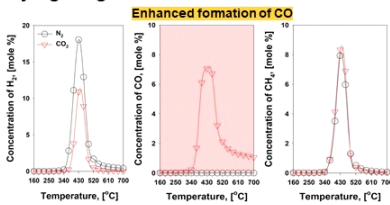
- Direct CO<sub>2</sub> capture



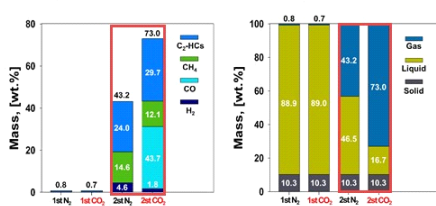
# Pyrolysis

## CO<sub>2</sub>-assisted pyrolysis

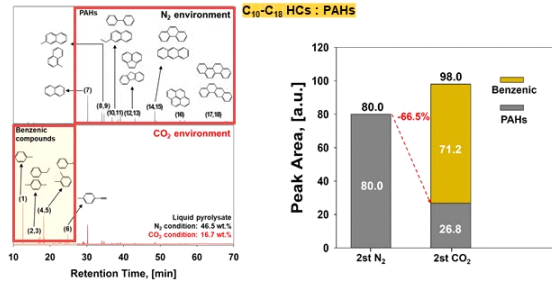
### Pyrogenic gases



### Cumulative concentration & mass balance



### Pyrogenic oil from two-stage pyrolysis of SFW

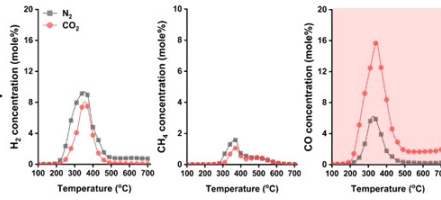


- (Gas) CO production was enhanced **despite the absence of O<sub>2</sub>**
- (Oil) CO<sub>2</sub> can control the **fate of toxic chemicals** through **homogeneous reaction**
- Catalytic pyrolysis can decrease the benzenic analogs

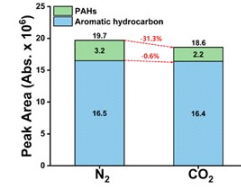
# Pyrolysis



Livestock carcasses (LSC)



Enhanced formation of gases



Decrease in aromatic analogues

## High density of livestock farming

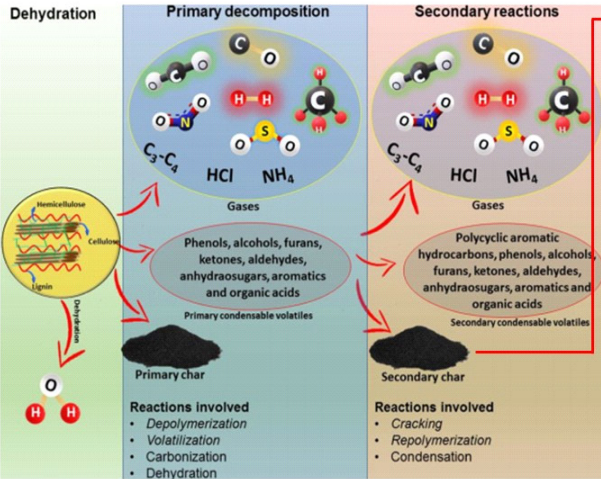
- Antibiotic residues
- Green house gases
- Confirmed that CO<sub>2</sub>-assisted pyrolysis can be utilized as a greenhouse gas mitigation technology

Table 1  
Carbon footprint and energy recovery potential of various LSC treatment systems (assuming high H<sub>2</sub> selectivity (≥96 %) via rWGSR).

Content	Landfill	Pyrolysis	
		N <sub>2</sub>	CO <sub>2</sub>
(1) CO <sub>2</sub> emission [g CO <sub>2</sub> -eq g <sup>-1</sup> LSC]	-	-	0.02
CH <sub>4</sub> emission	0.55	0.03	-
CO <sub>2</sub> emission	1.06	0.08	-
ΣCO <sub>2</sub> -eq emission [g CO <sub>2</sub> -eq g <sup>-1</sup> LSC]	16.48	0.86	0.48
(2) CO <sub>2</sub> reduction [g CO <sub>2</sub> -eq g <sup>-1</sup> LSC]	-	-	0.36
Biochar carbon sequestration	-	0.34	0.54
CO <sub>2</sub> utilisation	-	-	0.90
ΣCO <sub>2</sub> -eq reduction [g CO <sub>2</sub> -eq g <sup>-1</sup> LSC]	-	0.34	0.90
(3) Carbon footprint [g CO <sub>2</sub> -eq g <sup>-1</sup> LSC]	16.48	0.52	-0.42

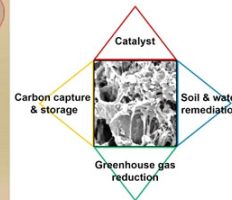
# Biochar

## Thermochemical conversion of biochar



✓ IPCC 2019 GL  
: Solid material generated by heating biomass to a temperature in excess of 350 °C under conditions of controlled and limited oxidant concentration to prevent combustion

✓ EBC (European biochar certificate)  
: Biochar is a porous, carbonaceous material that is produced by pyrolysis of biomass and is applied in such a way that the contained carbon remains stored as a long-term C sink or replaces fossil carbon in industrial manufacturing.



**Biochar properties**

- Carbon-Negative
- Porous material

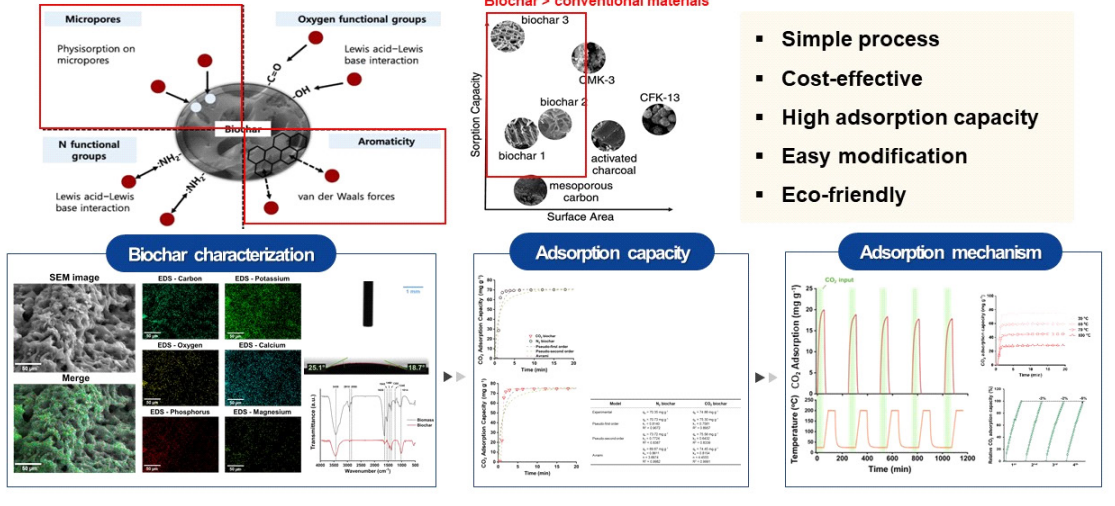
**Biochar application**

- Direct CO<sub>2</sub> capture
- Soil amendment

\* Source) Industrial biochar systems for atmospheric carbon removal: a review (2021, Environmental Chemistry Letters)

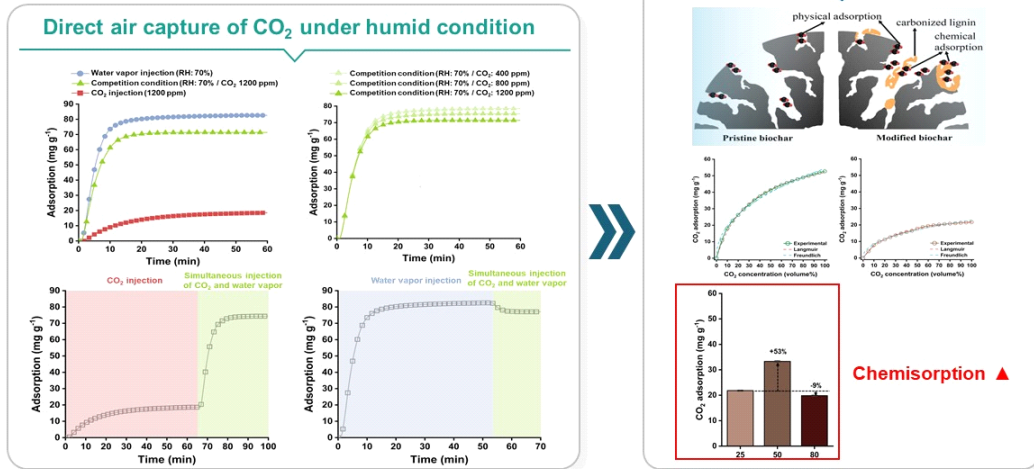
# Biochar

## CO<sub>2</sub> adsorption using biochar



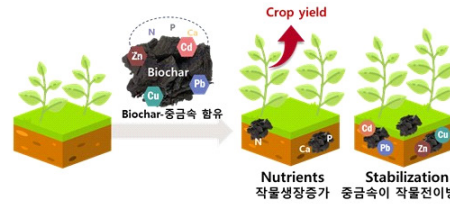
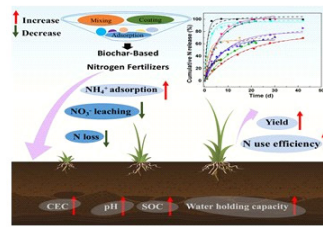
# Biochar

## CO<sub>2</sub> adsorption using biochar

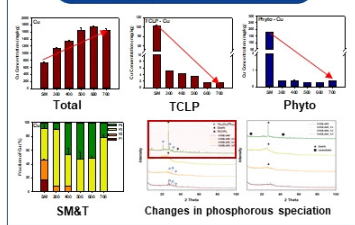


# Biochar

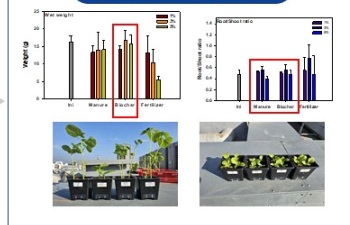
## ✓ Forage production using biochar



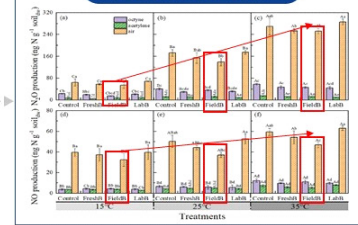
### Biochar characterization



### Forage production

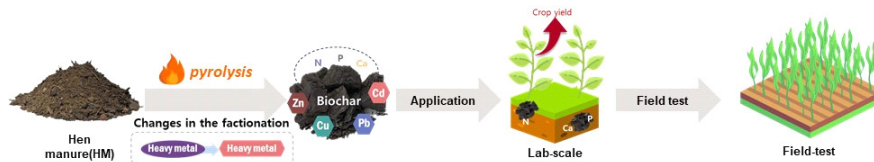


### GHG mitigation

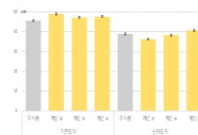


# Biochar

## ✓ Forage test: Expansion to field test



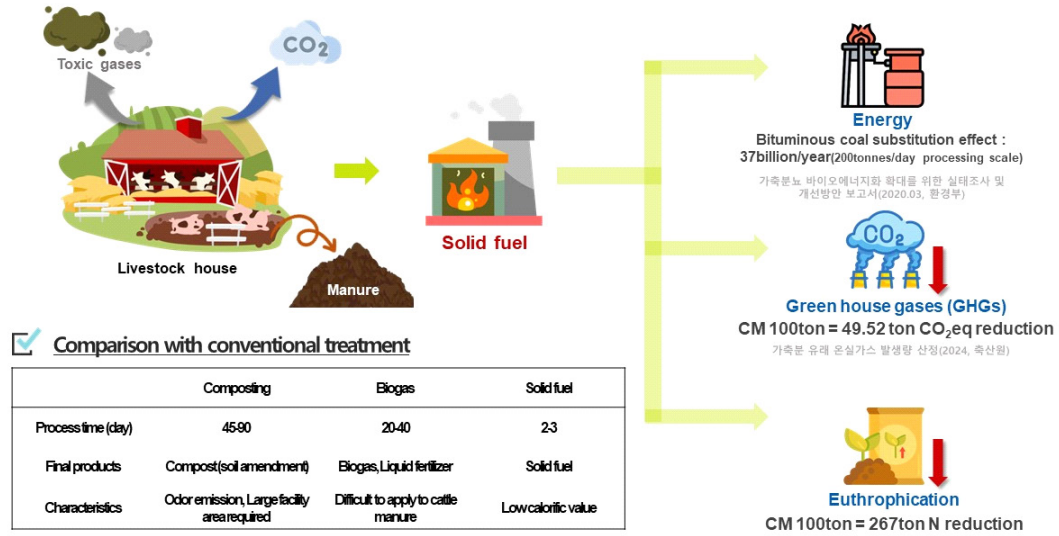
Biochar	Grassland
<ul style="list-style-type: none"> <li>High pH (Ca, Mg)</li> <li>Porous structure</li> <li>Cation exchange capacity (CEC)</li> <li>SOC stabilization</li> </ul>	<ul style="list-style-type: none"> <li>Acidified soils</li> <li>Low OM</li> </ul>



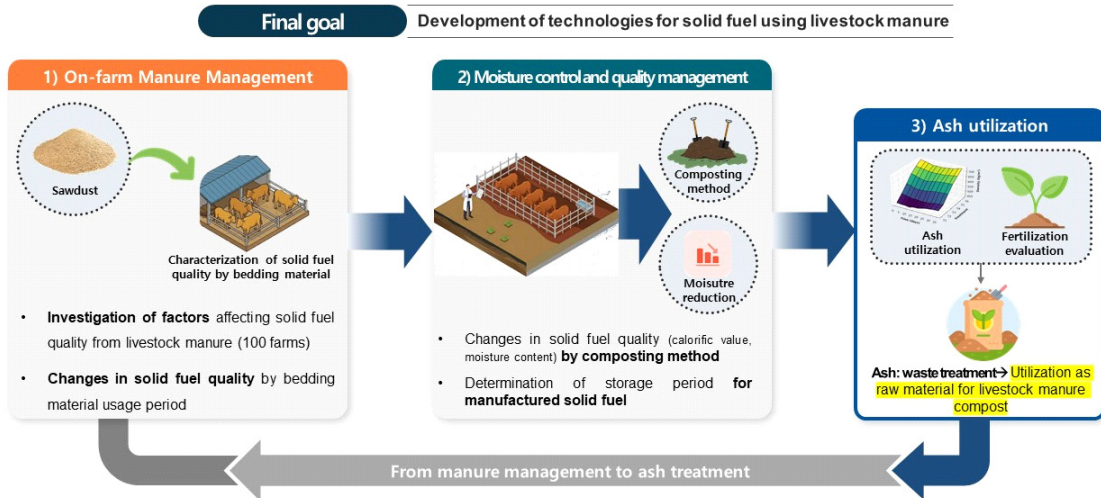
From the field test (Tall fescue)..

- Hen manure (HM) with 2.9% N showed clear potential as a soil fertilizer.
- The optimal application rate for forage yield was 6 ton ha<sup>-1</sup>

## Solid fuel

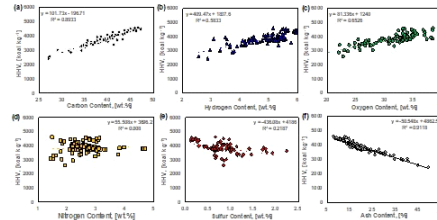
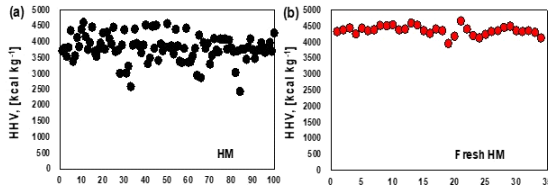


## Solid fuel



## Solid fuel

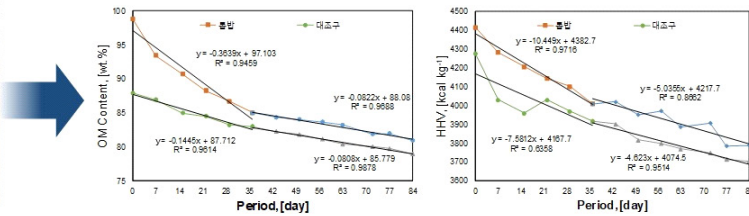
### 1. Manure Investigation of factors affecting solid fuel quality from livestock manure (100 farms)



- Solid fuel standard: 3,000kcal/kg (HHV: 4,200kcal/kg)
- Survey results:  $3,802.1 \pm 407.5$  kcal/kg (100 farms) vs  $4,383.2 \pm 140.9$  kcal/kg (fresh CM)
- \* manure excretion timing, bulking agent utilization, compost recycling
- Key factor: Organic matter ( $R^2$ : 0.9118)  $\rightarrow$  50.5 kcal/kg per 1% organic matter

## Solid fuel

### 2. Storage period Determination of the storage period of livestock manure



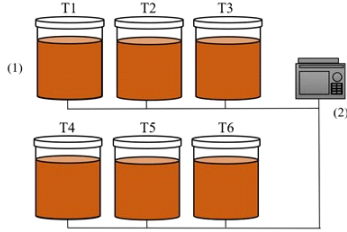
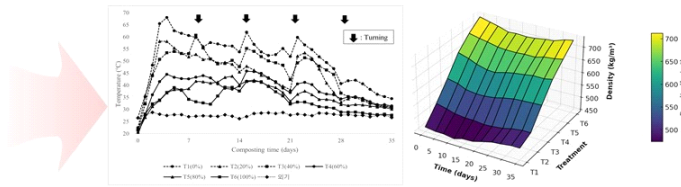
- (Problems) Aerobic fermentation during storage in barns  $\rightarrow$  reduction in heating value
- Evaluation of heating value changes in livestock manure during storage
- Optimal storage period: 90days

## Solid fuel

### 3. Ash Effect of ash level on composting performance

Ash addition level and sawdust replacement by treatment

	Composting treatment setup (kg)			Total (a+b+c)	Addition level (c/a)
	compost (a)	Bulking agent (b)	ash (c)		
<b>T1 (0%)</b>	87.2	21.5	0.0	108.7	<b>0%</b>
<b>T2 (20%)</b>	87.2	16.5	4.1	107.8	<b>5%</b>
<b>T3 (40%)</b>	87.2	11.9	7.9	107.0	<b>10%</b>
<b>T4 (60%)</b>	87.2	7.6	11.5	106.3	<b>14%</b>
<b>T5 (80%)</b>	87.2	3.7	14.8	105.6	<b>18%</b>
<b>T6 (100%)</b>	87.2	0.0	17.8	105.0	<b>22%</b>



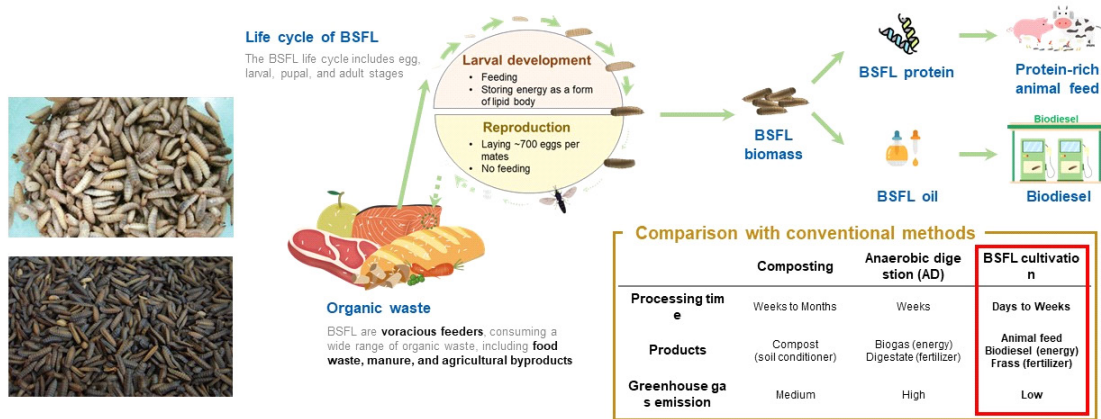
Experimental setup

- ✓ Temperature: Only T1 and T2 met the USDA composting safety standard (above 55 °C, 3 days or more)
  - ✓ (Density) High ash content → Increase density → Porosity ↓ + Fermentation ↓
  - ✓ (EA) Increase in mixing ratio → Organic matter ↓ → Composting inhibition
- \* Carbon content: T1: 40.0, T2: 35.0.....T5:21.7, T6:20.0

## Waste Upcycling

### ✓ Entomoremediation

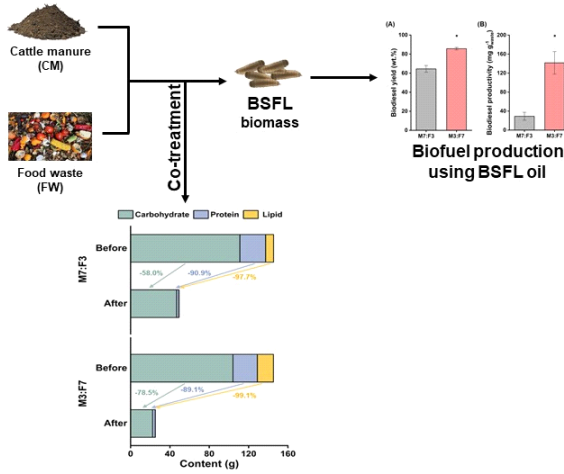
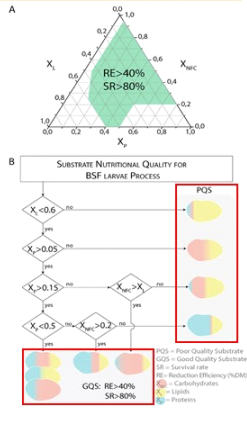
- BSFL are considered a sustainable bioconversion technology for waste management and resource recovery, as they rapidly decompose organic waste and convert it into protein-rich larval biomass and organic fertilizer.



# Waste Upcycling

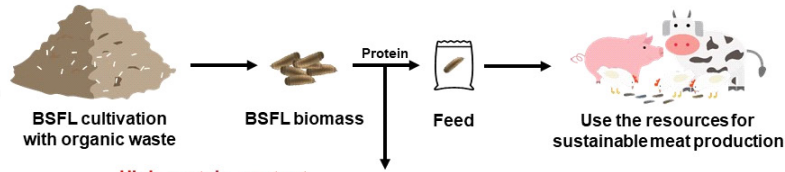
## ✓ Insect biomass (BSFL)

### Good Quality Substrate

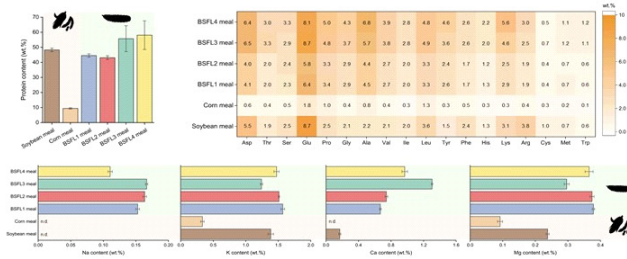


# Waste Upcycling

## ✓ Insect biomass (BSFL)



### High protein content



**Broiler**

- Leucine, Valine, Isoleucine

**Swine**

- Lysine, methionine, Cysteine

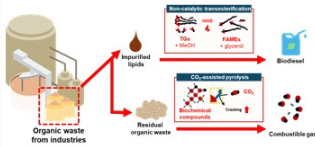
Compared to soybean meal,

- The amino acid compositions of BSFL were similar to Soybean meal
- BSFL-derived proteins have high potential as a livestock feed protein source
- BSFL: 42,471 - 48,345 kg protein ha<sup>-1</sup> y<sup>-1</sup>
- > Soybean: 1,174 kg ha<sup>-1</sup> y<sup>-1</sup>

## Future Research Topic

### Integrated platform

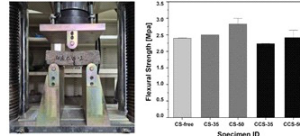
Integrated thermal and biological treatment for zero waste



- (before) single-process treatment
- **(Improved)** Integrated application of pyrolysis + biodiesel conversion → **Enhanced energy recovery**

### Waste valorization

Development of practical valorization strategies for biochar and ash



- (Problem) limited utilization of biochar and ash (high salinity and heavy metals)
- **(solution)** Cross-industry valorization (e.g., paving blocks)

### Emission control

Livestock odor monitoring and mitigation technology



- Emission factor development by livestock management strategies (composting, slurry)
- **Meseasurement method (adsorption tube) + mitigation technologies (Photocatalyst)**

Enhancement of livestock environment through multidisciplinary approaches

# Thank you

□ □ □ □ □ □ □ □

Sustainable Livestock Waste Valorization through Intergrated Conversion Process

# THANK YOU

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**Proceedings of 2026 Annual Congress of KSAST Vol. II**

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