

Technologies to Address Climate Change and Improve the Health of Ruminants by Utilizing the Microbiome and Metabolome

김 명 후

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Curriculum Vitae

- ▶ 2025~현재 서울대학교 농업생명과학대학 동물생명공학 전공 부교수
- ▶ 2022~2025 부산대학교 생명자원과학대학 동물생명자원과학과 부교수
- ▶ 2018~2022 부산대학교 생명자원과학대학 동물생명자원과학과 조교수
- ▶ 2016~2018 베일러 의과대학 박사후 연구원
- ▶ 2010~2015 퍼듀대학교 수의과대학 영양면역학 이학박사
- ▶ 2007~2009 서울대학교 농생명공학부 농학석사
- ▶ 2000~2006 서울대학교 동물생명자원과학과 농학사

2026 KSAST
Animal Microbiome

Technologies to Address Climate Change and Improve the Health of Ruminants by Utilizing the Microbiome and Metabolome

 Seoul National University
College of Agriculture and Life Science
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Myunghoo Kim

01

Microbiome and Metabolome in Animals

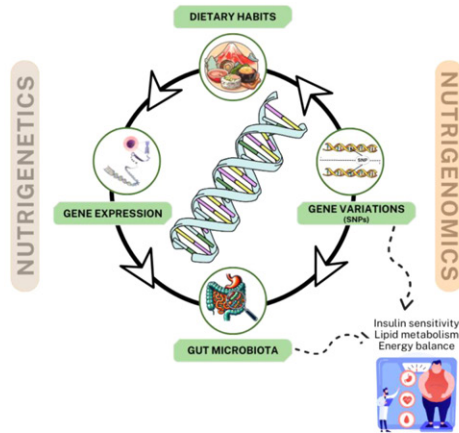
4

Understanding the factor determining animal phenotypes



Phenotype = Genetics + Environment

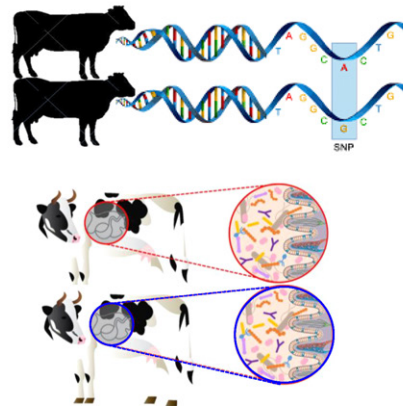
Animal genetics, coupled with environmental influences, dictate how we metabolize the **nutrients** that we consume and how this shapes our **growth, function, and Health.**



5

Nutrigenetics: Single Nucleotide Polymorphism & Microbiome

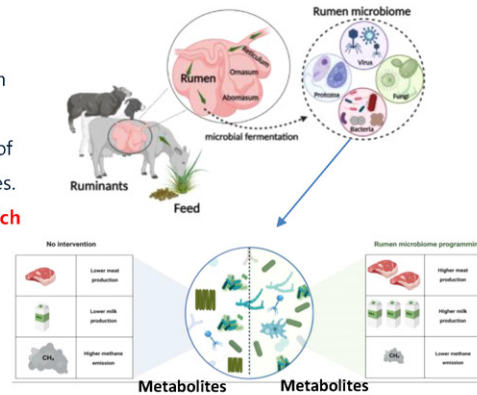
- **Nutrigenetics:** A field that explains biological variations caused by genes by describing how metabolic changes, such as the absorption and utilization of nutrients, are influenced by gene mutations.
- Even within the same organism, the metabolic processes related to nutrients vary due to genetic predispositions.
- This phenomenon is attributed to **single nucleotide polymorphisms (SNPs)**, which are characteristics of the genetic information of living beings.
- The **microbiome** plays a crucial role in the field of nutrigenetics for ruminants due to several key factors: Nutrient digestion, Metabolite production, disease resistance, and feed conversion efficiency.
- Since each individual has **different SNPs and microbiome**, the effects or responses to nutrient intake can vary.



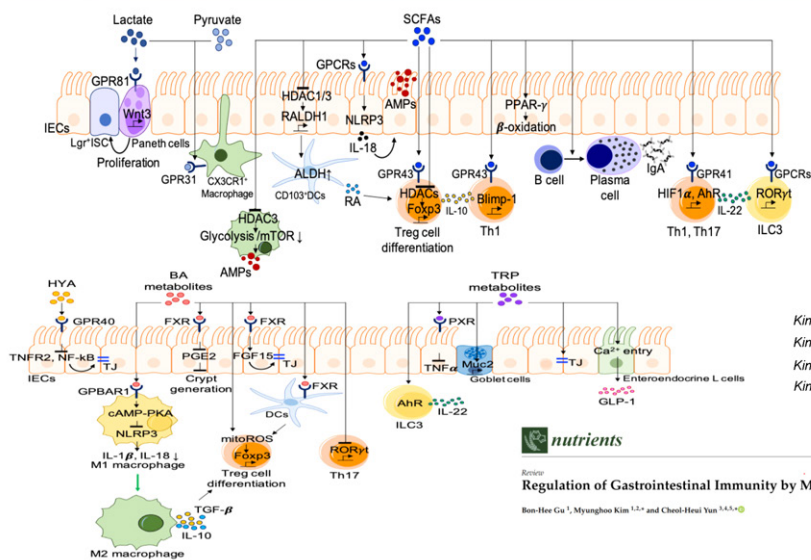
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Nutrigenomics: Microbiome to dietary responses in Animals

- **Nutrigenomics**: is the study of how nutrients affect gene expression and how genetics affect nutrition. It's a field that combines health, diet, and genomics.
- Nutrients can induce huge changes in **gut microbiome** composition and **metabolic gene expression**.
- More importantly, the microbiome play a central role in regulation of gene expression in host tissue by various signals such as metabolites.
- Understanding **specific genes and proteins, the expression of which is influenced by nutrients**, are identified using genomics tools — such as transcriptomics, proteomics and metabolomics — which subsequently allows the regulatory pathways through which diet influences homeostasis to be identified.
- Also, **system biology** can be further applied.



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Kim et al., 2016, Cell Host & Microbe
 Kim et al., 2018, Gut microbes
 Kim et al., 2013, Gastroenterology
 Kim et al., 2018, Eur J Immunol

nutrients

MDPI

Review
 Regulation of Gastrointestinal Immunity by Metabolites

Bon-Hee Gu¹, Myunghoo Kim^{1,2,*} and Chool-Heui Yun^{1,3,4,5,*}

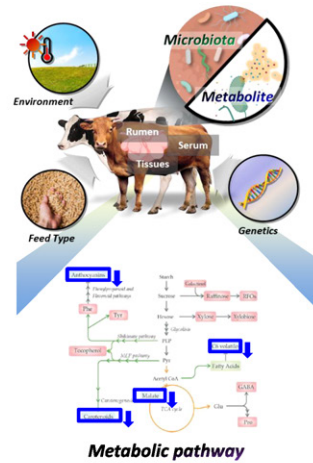
11

Metabolome represents the physiological condition of Animals

Metabolomics: A comprehensive study that systematically analyzes the circulation and secretion changes of metabolites within cells or tissues and reinterprets metabolic networks in relation to various physiological and pathological states.

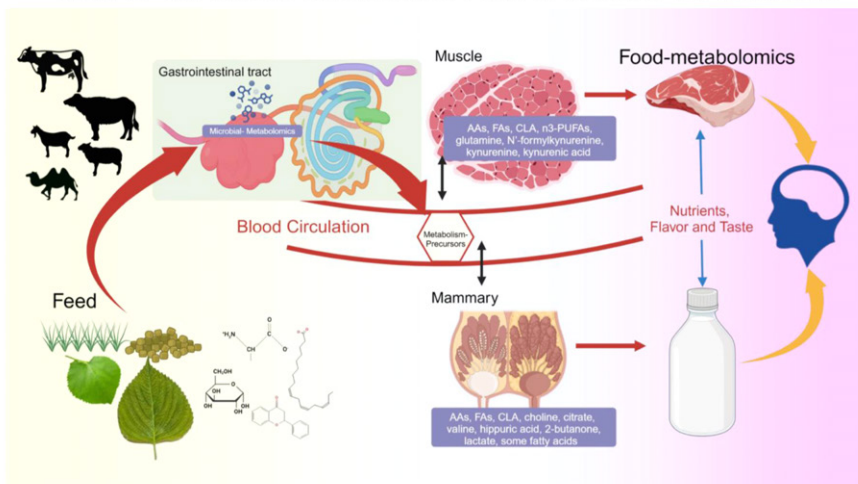
✓ Understanding metabolic changes associated with specific diseases requires ultra-precise analytical techniques for detecting and confirming metabolite changes, as well as statistical analyses to interpret the results concerning the physiological condition of the organism.

✓ Metabolomics has the advantage of reflecting changes in biochemical substances directly related to physiological or pathological functions of proteins, allowing these metabolic changes to be explained through phenotypes.



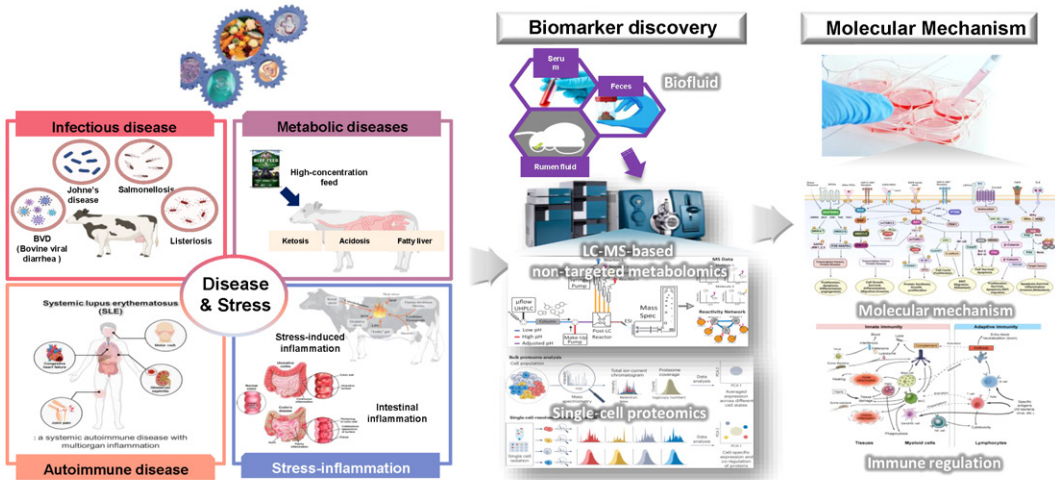
12

Flow of the Metabolome from Feed to Human via Livestock

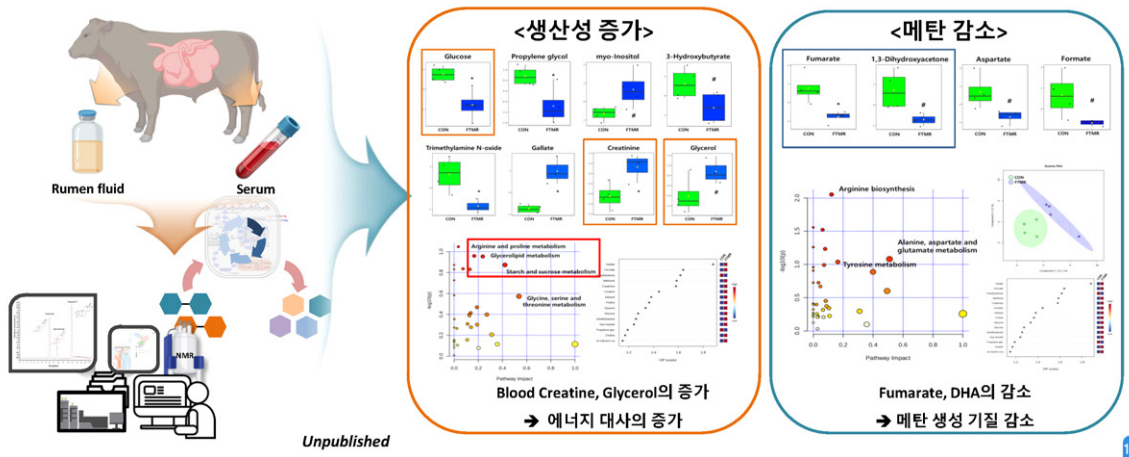


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Metabolites Control Immunity & Metabolism in Animals



대사체 분석을 통한 한우 기능성 F-TMR 급여 시 메탄 저감 및 생산성 향상 기전 규명



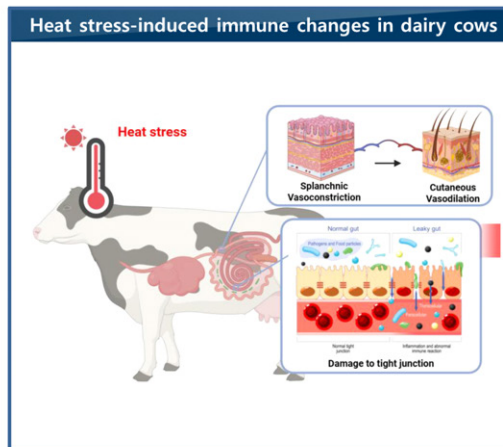
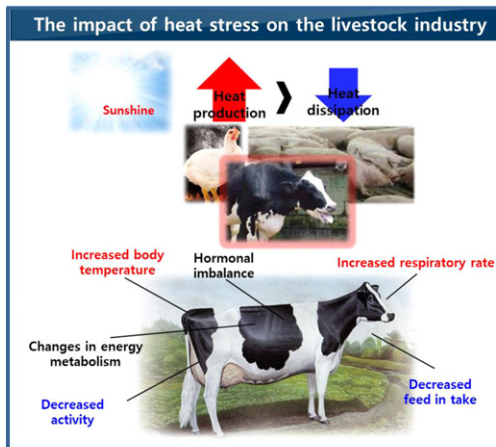
02

Microbiome & Metabolome in Heat stressed-Dairy Cow

Chapter 2

2-1. | Heat Stress-Dairy Cow | Metabolism & Immunity

“-----” Adverse Effects of Heat Stress on Dairy Cows



18

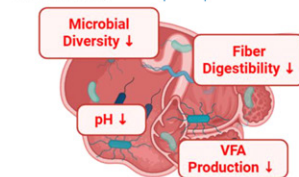
Altered Rumen Environment: Microbial Shifts & Abnormal Fermentation

Shifts in Microbial Communities

- ① **Fibrolytic bacteria** ↓
→ Leads to impaired fiber digestion
- ② **Amylolytic bacteria** ↑↑
→ Results in decreased host starch utilization
- ③ **Lactic acid bacteria** ↑↑
→ Causes accumulation of lactic acid (pH drop)
- ④ **Overall microbial diversity** ↓

Microbial shifts lead to severe ruminal dysbiosis & fermentation dysfunction.

Saliva intake ↓



Energy deficit due to impaired fermentation

Imbalance in Fermentation Patterns

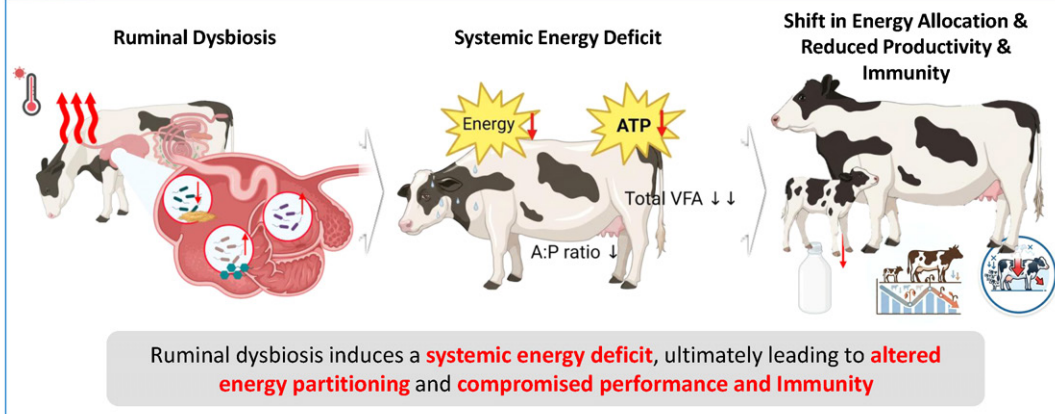
- ① **Total VFA production** ↓
→ Driven by reduced feed intake and impaired fiber digestion
→ Leads to severe energy deficit for the host
- ② **Altered VFA ratios**
→ Decreased Acetate-to-Propionate (A:P) ratio
→ Results in milk fat depression (MFD)

Altered fermentation profiles severely restrict energy availability & degrade milk quality.

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Systemic Consequences: Energy Deficit and Compromised Performance

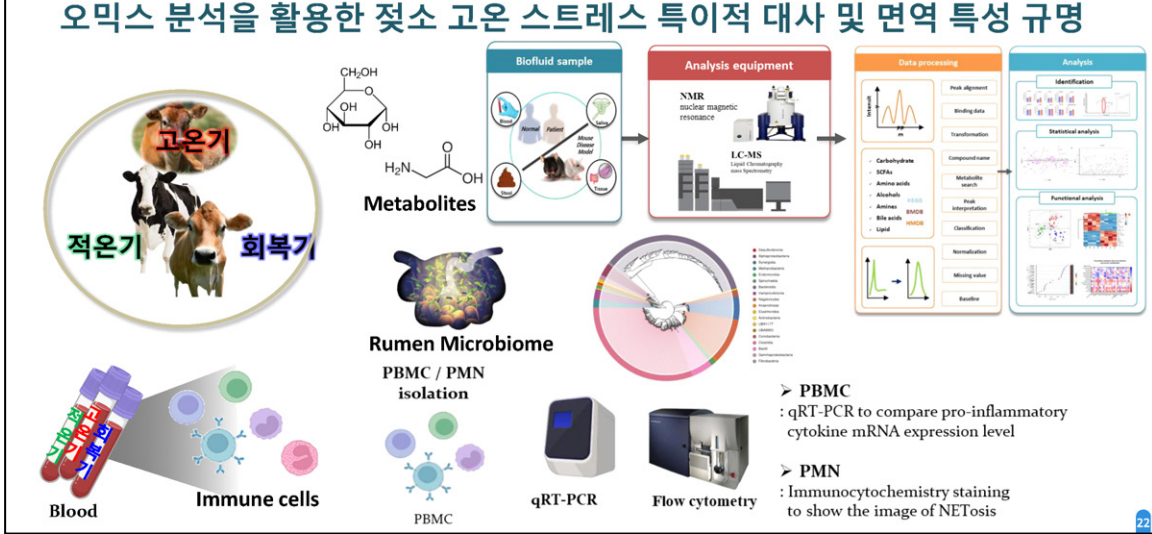
Rumen Environment under Thermoneutral Conditions



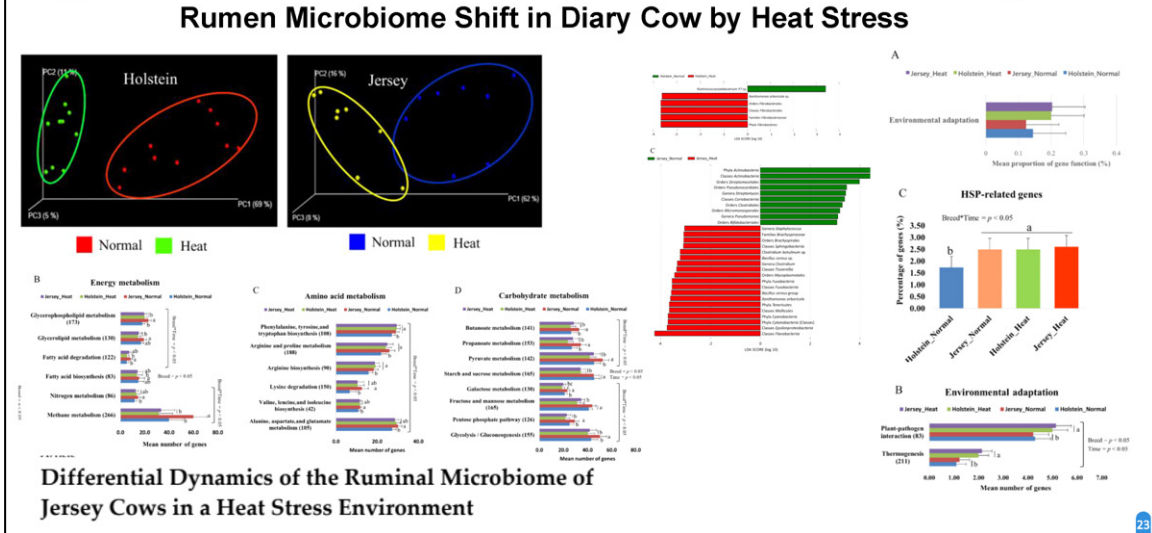
Ruminal dysbiosis induces a **systemic energy deficit**, ultimately leading to **altered energy partitioning** and **compromised performance and immunity**

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“ 오믹스 분석을 활용한 젖소 고온 스트레스 특이적 대사 및 면역 특성 규명 ”



“ Rumen Microbiome Shift in Dairy Cow by Heat Stress ”

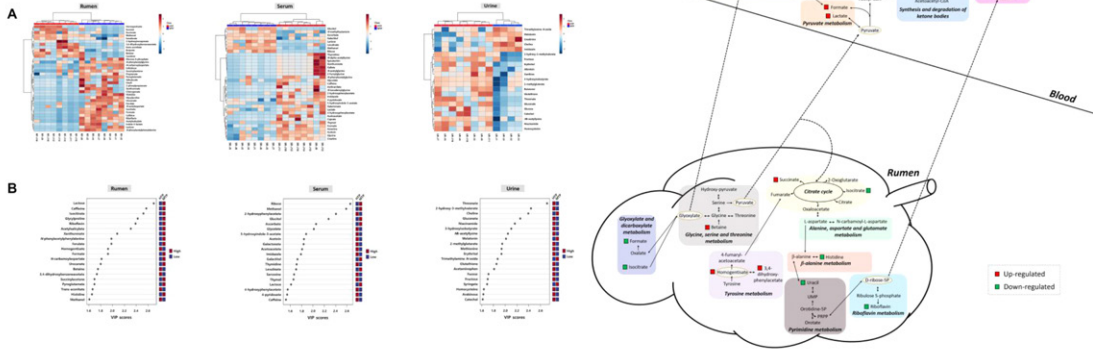


Differential Dynamics of the Ruminal Microbiome of Jersey Cows in a Heat Stress Environment

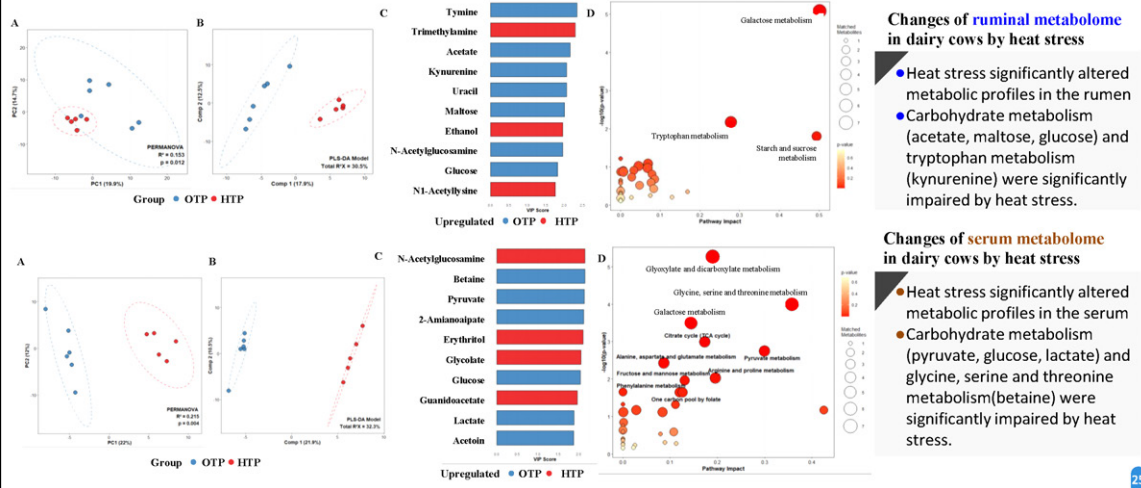
Metabolome 분석 활용 젖소 고온 스트레스 특이적 대사 특성 규명

Animal Nutrition

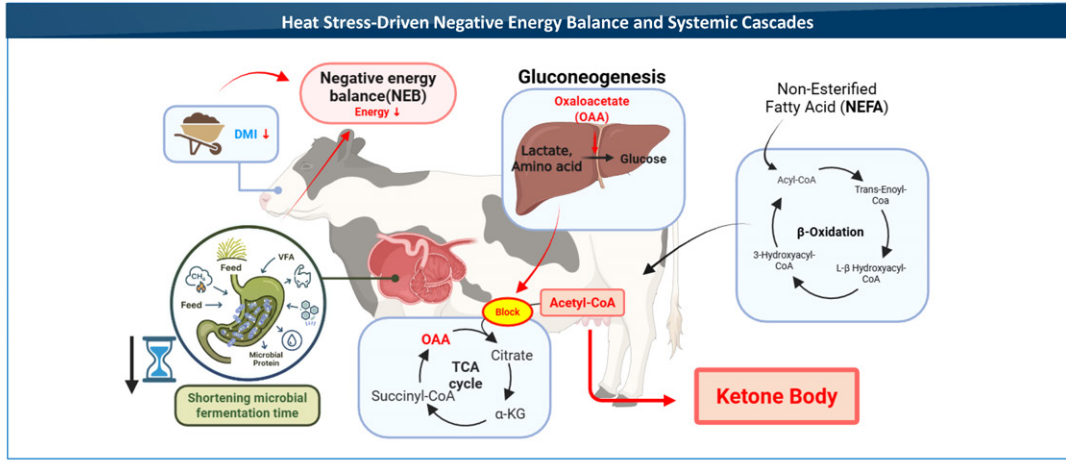
Metabolomic and transcriptomic study to understand changes in metabolic and immune responses in steers under heat stress



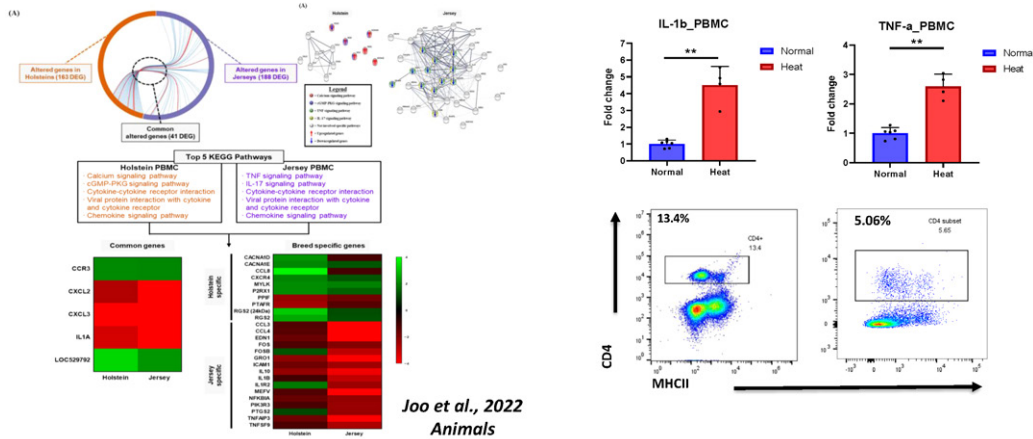
Changes of metabolome phenotype in Dairy Cow by Heat Stress



Shifts in Host Metabolism and Negative Energy Balance



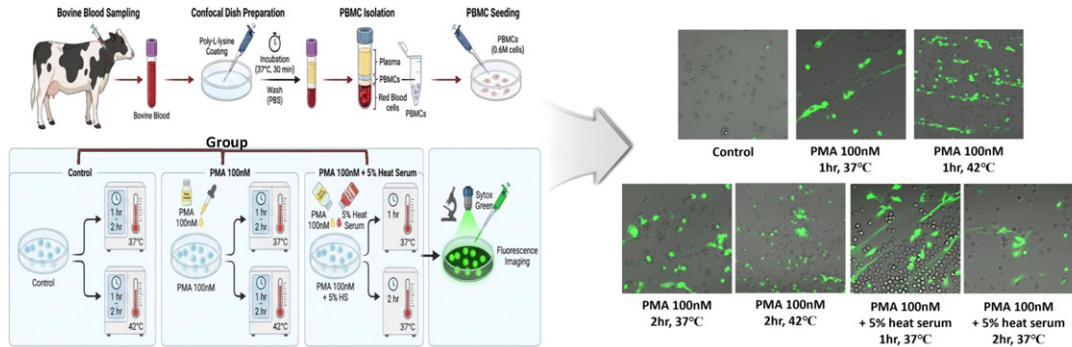
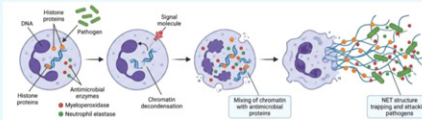
Changes of immune phenotype in Dairy Cow by Heat Stress



Changes of immune phenotype in Dairy Cow by Heat Stress

NETosis (Neutrophil Extracellular Traps Formation)

Cell death process in which **neutrophils**, a type of immune cell, die and release their **intracellular DNA, histone proteins, and antimicrobial enzymes** into the extracellular space like a trap to eradicate pathogen.

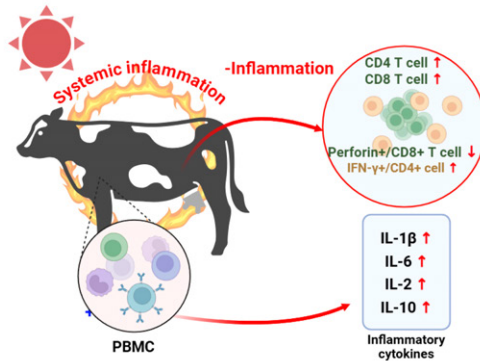


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Shifts in Host Metabolism and Negative Energy Balance

Heat stress can induce systemic inflammatory responses in dairy cows.

Heat stress



① Shifts in Systemic Immune Cell Populations

→ Increased proportions of CD4+ and CD8+ T cells

② Alterations in Pro-inflammatory Cytokine Expression

→ Significant increase in TNF-α, IL-1β, and IL-6 levels
→ Leads to increased energy expenditure for immune maintenance

Reduced productivity due to inefficient energy expenditure.

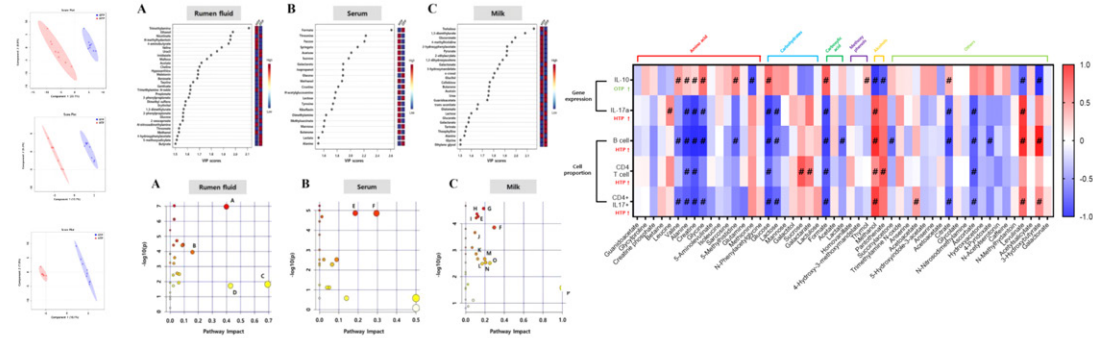
29

Metabolome 분석 활용 젖소 고온 스트레스 특이적 대사 특성 규명

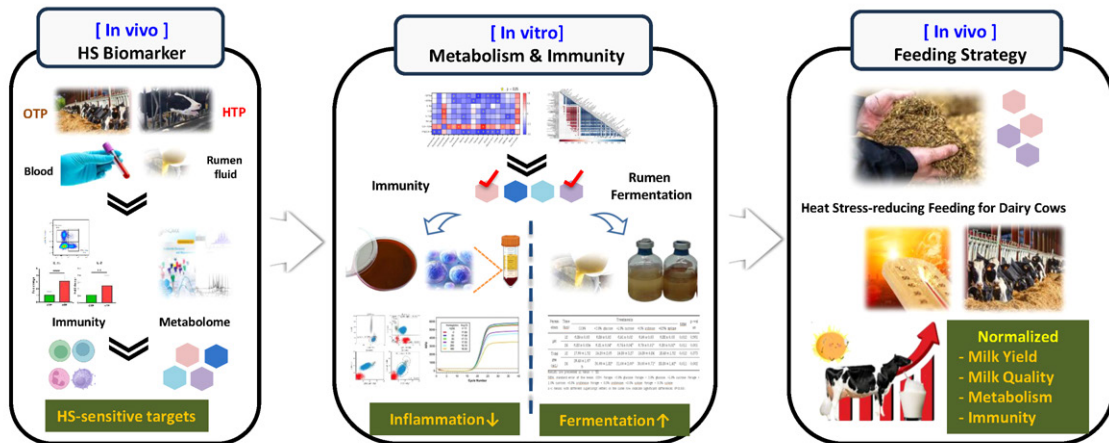


Integrated metabolome and immunity analysis of immune-physiological responses in dairy cows under heat stress condition

Jun Sik Eom a, Sangjin Lee a, Joonpyo Oh a, Byeong Cheol Ban, Yeeun Kim, Goeun Han, Bon-Hee Gu, Eun-Tae Kim, Sang-Bum Kim, Sung Sill Lee* and Myunghoo Kim*



WORKFLOW: Nutritional Strategy to Mitigate Heat Stress for Dairy Cow

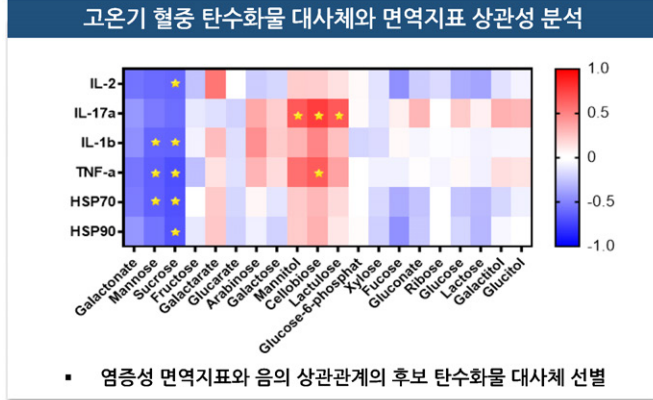
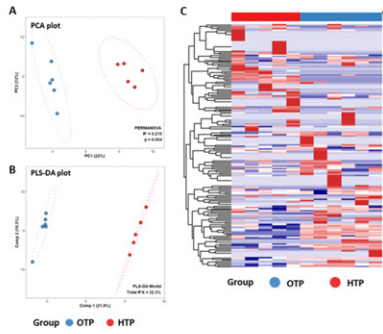


OTP: Optimal Temperature/Humidity Period
HTP: High Temperature/Humidity Period

2-3. | Heat Stress Mitigation | Nutrition for Heat stressed-Dairy Cow

“ 고온기 대응 젖소 대사 및 소화율 개선 탄수화물 기반 사료소재 발굴 ”

□ 고온기 젖소 스트레스 저감을 위한 탄수화물 공급 전략 수립



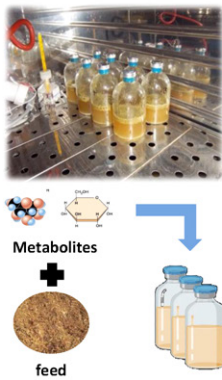
■ 염증성 면역지표와 음의 상관관계의 후보 탄수화물 대사체 선별

2-3. | Heat Stress Mitigation | Nutrition for Heat stressed-Dairy Cow

“ 고온기 대응 젖소 대사 및 소화율 개선 탄수화물 기반 사료소재 발굴 ”

□ In vitro 평가를 통한 탄수화물 기반 에너지 보충 사료 선정

Table . Effect of soluble sugars on pH, gas production, NH₃-N, and VFA after 24 h incubation.



Parameters	Time (h)	Treatments					SEM	p-value
		CON	glucose	sucrose	arabinose	xylose		
pH	12	6.89 ± 0.03	6.89 ± 0.02	6.91 ± 0.02	6.90 ± 0.03	6.88 ± 0.03	0.012	0.5608
	24	6.83 ± 0.03 ^a	6.81 ± 0.04 ^a	6.74 ± 0.04 ^{ab}	6.79 ± 0.01 ^a	6.80 ± 0.02 ^a	0.011	0.0010
Total gas (mL)	12	17.60 ± 1.52	19.20 ± 2.05	19.80 ± 3.27	19.80 ± 0.84	18.40 ± 1.52	0.012	0.3733
	24	26.40 ± 1.67 ^b	30.60 ± 1.82 ^a	31.00 ± 2.00 ^a	30.00 ± 0.71 ^a	28.80 ± 1.92 ^a	0.011	0.0024
NH ₃ -N (mg/dL)	12	5.98 ± 0.16	4.66 ± 0.21	5.92 ± 0.36	6.48 ± 2.06	5.83 ± 0.81	0.339	0.1740
	24	6.77 ± 1.73 ^{bc}	6.03 ± 0.68 ^c	10.79 ± 1.80 ^a	9.38 ± 2.62 ^{ab}	11.44 ± 2.49 ^a	0.868	0.0018
Total VFA (mmol/L)	12	45.94 ± 2.54 ^a	46.24 ± 1.36 ^a	44.01 ± 1.07 ^a	41.83 ± 1.39 ^b	44.49 ± 1.21 ^a	0.677	0.0023
	24	46.59 ± 3.51	48.21 ± 2.62	49.66 ± 1.84	50.95 ± 2.69	46.89 ± 2.71	1.631	0.3437
Acetate (mmol/L)	12	27.44 ± 1.27 ^a	28.02 ± 0.40 ^a	27.0 ± 0.45 ^{ab}	26.15 ± 0.87 ^b	27.42 ± 0.43 ^a	0.338	0.0233
	24	28.25 ± 1.36	28.95 ± 1.29	30.30 ± 0.99	30.32 ± 1.60	29.53 ± 1.14	0.853	0.4190
Propionate (mmol/L)	12	10.59 ± 0.62 ^{ab}	10.76 ± 0.78 ^a	10.07 ± 0.27 ^{bc}	9.61 ± 0.34 ^a	10.21 ± 0.28 ^b	0.161	0.0011
	24	11.10 ± 0.78	11.81 ± 1.02	12.29 ± 0.59	12.15 ± 1.07	11.13 ± 0.59	0.445	0.2446
Butyrate (mmol/L)	12	7.91 ± 0.73	7.46 ± 1.36	6.94 ± 0.70	6.07 ± 1.13	6.87 ± 1.57	0.440	0.1028
	24	7.24 ± 1.00	7.45 ± 0.67	7.07 ± 0.23	8.47 ± 1.54	6.23 ± 1.46	0.546	0.1650
A:P	12	2.59 ± 2.54 ^b	2.60 ± 0.02 ^b	2.68 ± 0.06 ^a	2.72 ± 0.05 ^a	2.68 ± 0.04 ^a	0.020	0.0011
	24	2.55 ± 0.05 ^{ab}	2.46 ± 0.04 ^b	2.47 ± 0.05 ^b	2.50 ± 0.03 ^b	2.66 ± 0.11 ^a	0.034	0.0098

2-3. | Heat Stress Mitigation | Nutrition for Heat stressed-Dairy Cow

“-----”
 고온기 대응 젖소 대사 및 소화율 개선 탄수화물 기반 사료소재 발굴

□ In vitro 평가를 통한 탄수화물 기반 에너지 보충 사료 선정

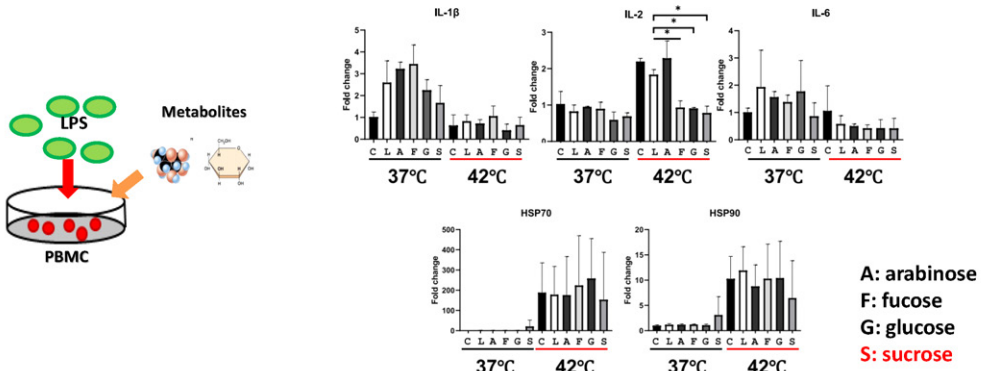
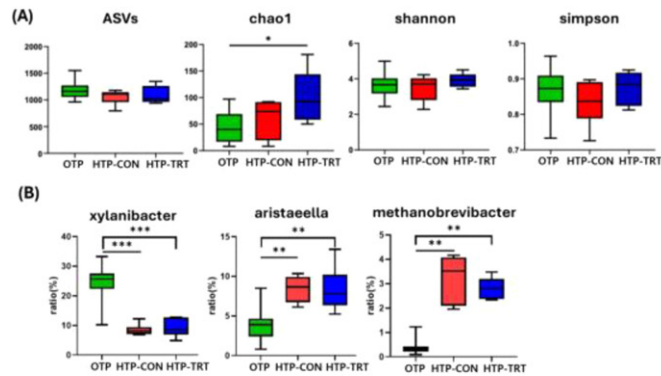


Fig. Effects of carbohydrate metabolites on cytokine and HSP expression in PBMCs of dairy cows.

2-3. | Heat Stress Mitigation | Nutrition for Heat stressed-Dairy Cow

“-----”
 고온기 대응 젖소 대사 및 소화율 개선 탄수화물 기반 사료소재 발굴

□ Sucrose 첨가제 급여에 따른 홀스타인 젖소 대사 개선 효능 평가



2-3. | Heat Stress Mitigation | Nutrition for Heat stressed-Dairy Cow

“ 고온기 대응 젖소 대사 및 소화율 개선 탄수화물 기반 사료소재 발굴 ”

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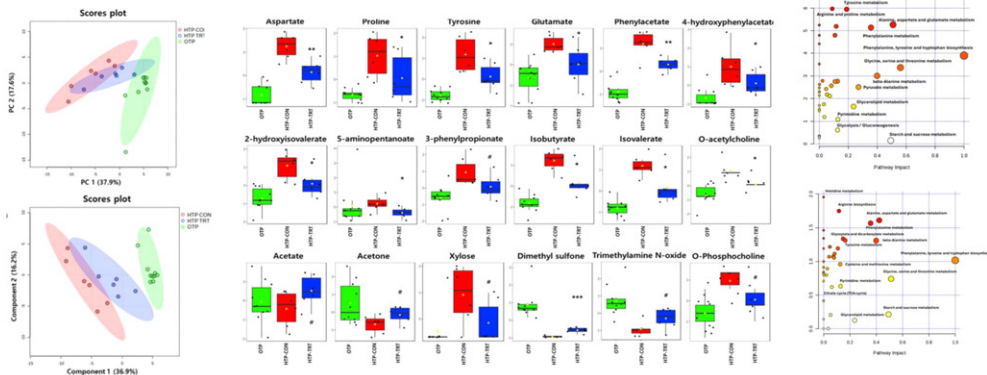


Fig. Differential ruminal metabolome of Heat stressed Holstein dairy with or without sucrose supplementation.

2-3. | Heat Stress Mitigation | Nutrition for Heat stressed-Dairy Cow

“ 고온기 대응 젖소 대사 및 소화율 개선 탄수화물 기반 사료소재 발굴 ”

□ Sucrose 첨가제 급여에 따른 홀스타인 젖소 면역 개선 효능 평가

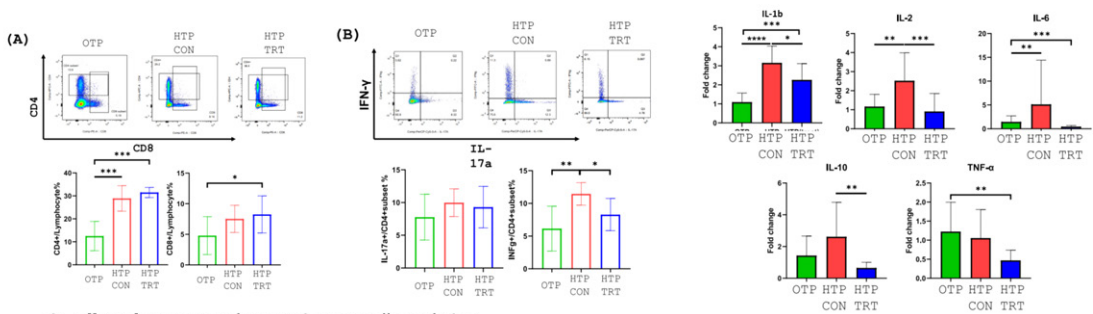
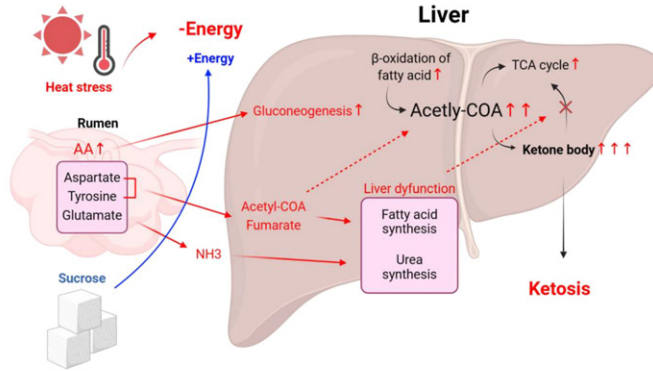


Fig. Effect of sucrose supplementation on T cell population in PBMCs of heat-stressed dairy cow.

Fig. Effect of sucrose supplementation on cytokine expression in PBMCs of heat-stressed dairy cow.

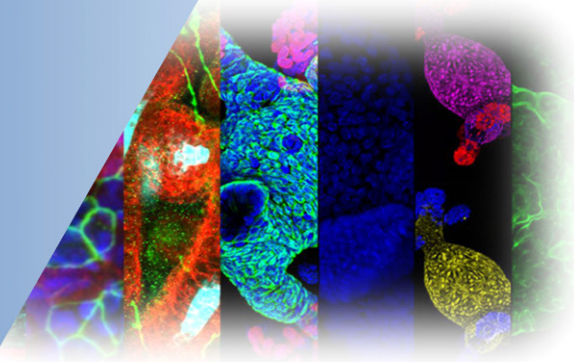
2-3. | Heat Stress Mitigation | Nutrition for Heat stressed-Dairy Cow

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고온기 대응 젖소 대사 및 소화율 개선 탄수화물 기반 사료소재 발굴



Potential regulatory mechanism of sucrose administration on metabolic process in dairy cows with heat stress.

03



Gut Immunity Development of neonatal calves

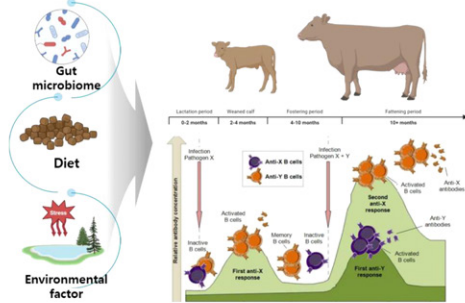
3-1. | Functional Nutrition

신생송아지 장관면역 발달 유도를 통한 강건성 향상 기술

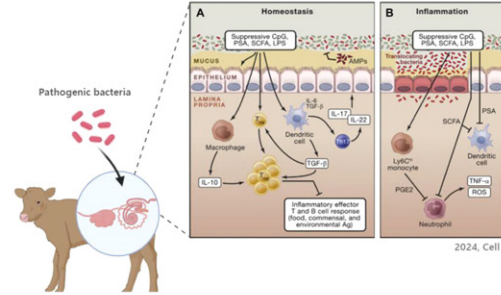
[미개척 연구분야 : 송아지 장관면역 발달과 조절 기전 규명]

송아지 성장에 따른 장관면역체계 발달

송아지 항병력에서 장관면역의 기능적 역할 이해



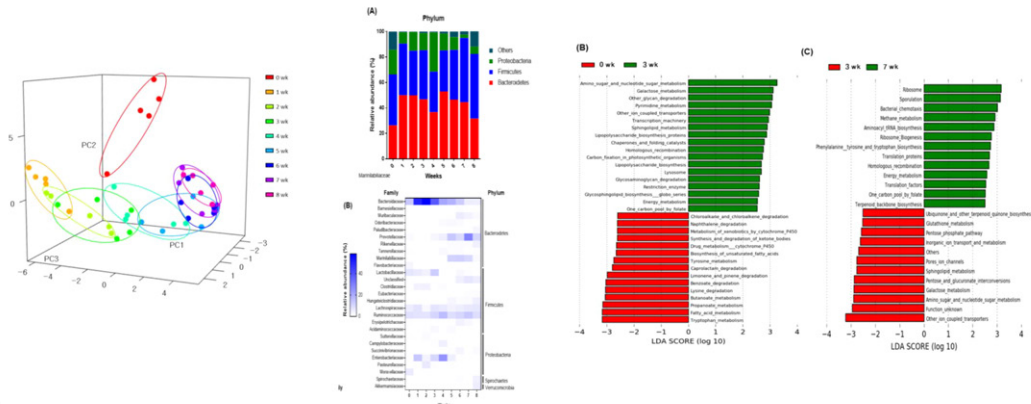
Development of Intestinal Immunity in Calves Influenced by Various Factors



Infection Resistance in the Development of Calf Intestinal Immunity

3-1. | Functional Nutrition | Microbiome & Metabolites

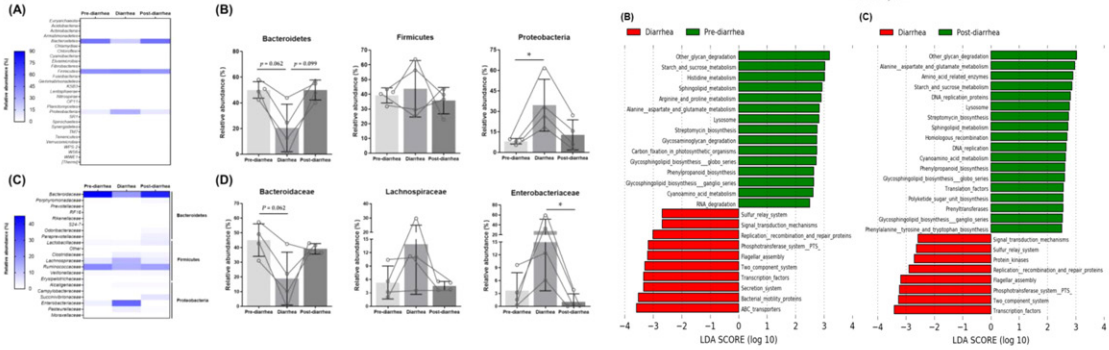
신생송아지 발달에 따른 장내 마이크로바이옴 변화



Article
Dynamic Changes in Fecal Microbial Communities of Neonatal Dairy Calves by Aging and Diarrhea

3-1. | **Functional Nutrition** | Microbiome & Metabolites

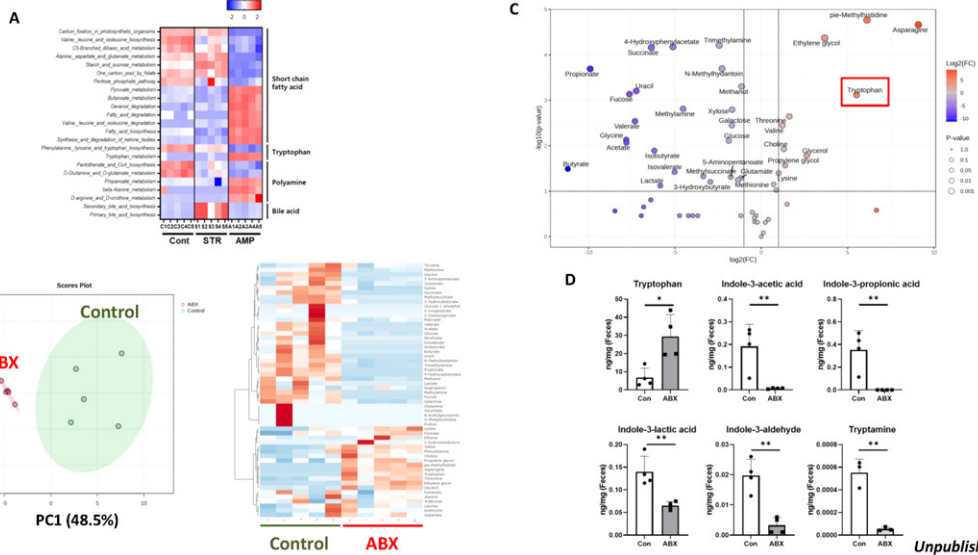
“ 신생송아지 설사 발생에 따른 장내 마이크로바이옴 변화 ”



Article
Dynamic Changes in Fecal Microbial Communities of Neonatal Dairy Calves by Aging and Diarrhea

48

3-2. | **Metabolites** | Gut health & Immunity



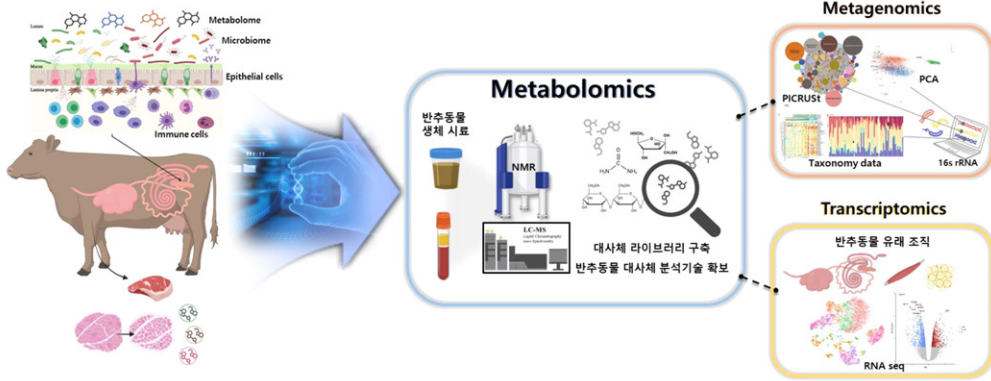
Unpublished 51

3-3. | Ongoing Research : Gut Environment for immunity & Metabolism

반추동물 대사경로 정보를 활용한 정밀영양사양기술

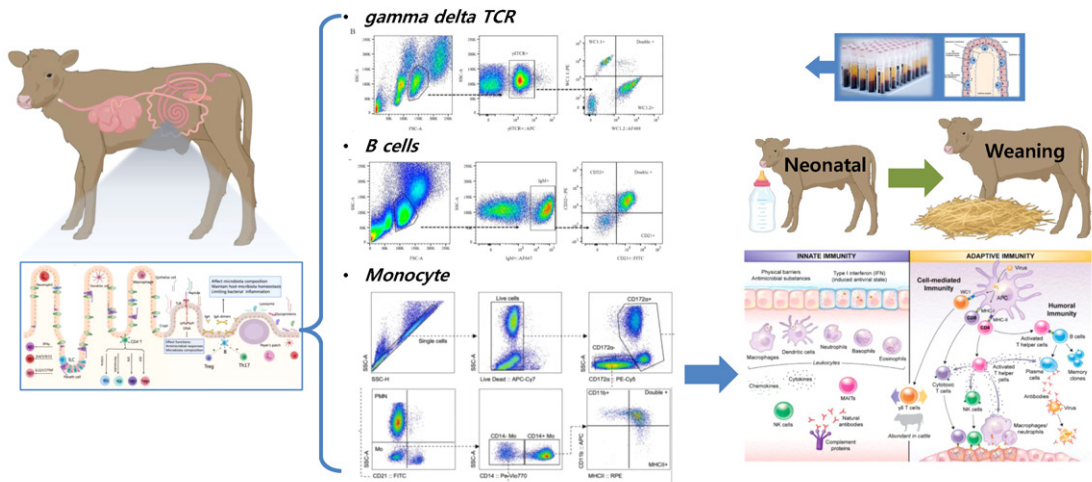
[미개척 연구분야 : 메타볼롬 분석을 통한 반추동물 대사경로 변화 특성 규명]

- 반추동물 biofluid 메타볼롬 라이브러리 부재
- 멀티오믹스 기반 반추동물 대사생리 변화 기전 규명



3-3. | Ongoing Research : Gut Environment for immunity & Metabolism

송아지 장관환경 조절을 통한 강건성 향상 기술: 송아지 장관면역 분석



3-3. | Ongoing Research : Gut Environment for immunity & Metabolism

송아지 장관환경 조절을 통한 생산성·강건성 향상 기술

미개척 연구분야 : 장내미생물-대사체 신호에 의한 송아지 면역·대사 조절 기전

- ◆ NGS 분석 기반 장내 마이크로바이옴 연구 한계
- ◆ 실증자원을 활용한 반추동물 장관환경 개선 기술

