断绝饲料生产与猪场疾病的生物防疫最新研究报告

Prevention of disease transmission from feed mill to pig farms

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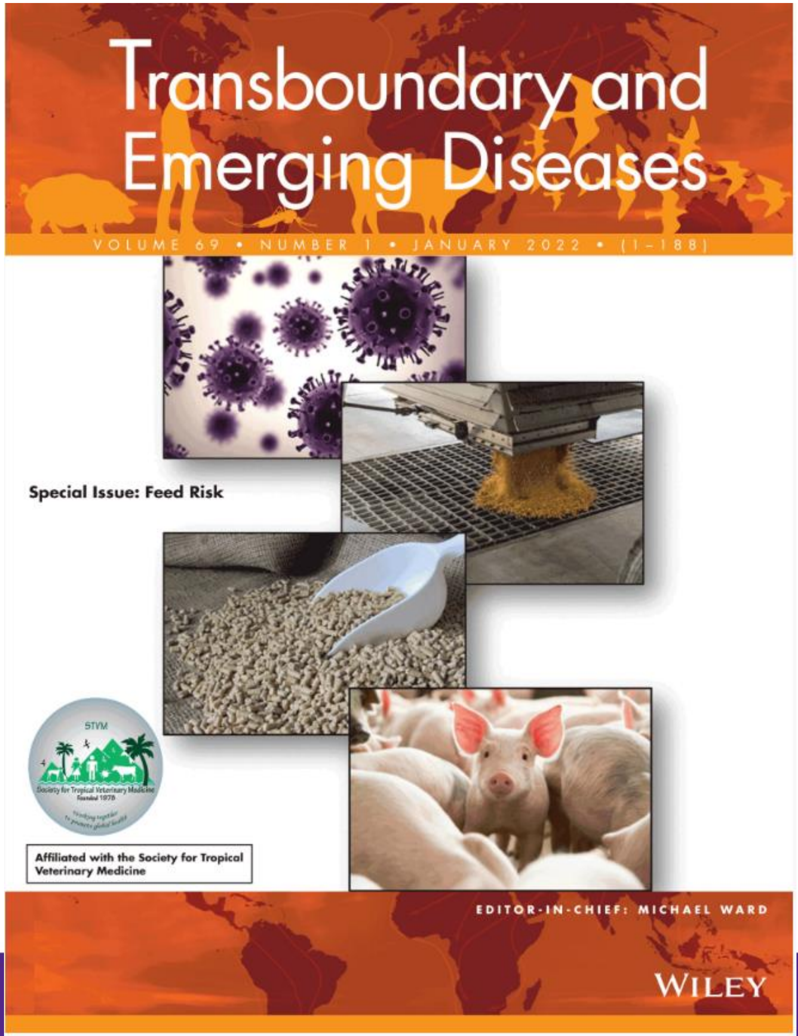
在饲料和/或饲料原料中存活的病原体 Pathogens capable of surviving in feed and/or feed ingredients

- 细菌 Bacteria
  - *沙门氏菌 Salmonella* spp.
  - *大肠杆菌 Escherichia coli*
- 病毒 Viruses
  - 猪流行性腹泻病毒 Porcine epidemic diarrhea virus (PEDV)
  - 非洲猪瘟病毒 African swine fever virus (ASFV)
  - 塞内卡病毒A Senecavirus A (SVA)
  - 猪瘟病毒 Classical swine fever virus (CSF)
  - 伪狂犬病毒 Pseudorabies virus (PRV)
  - 口蹄疫 Foot and mouth disease (FMD)
- 其他？ Others?



原料中病原体的存活情况
Pathogen survival in ingredients

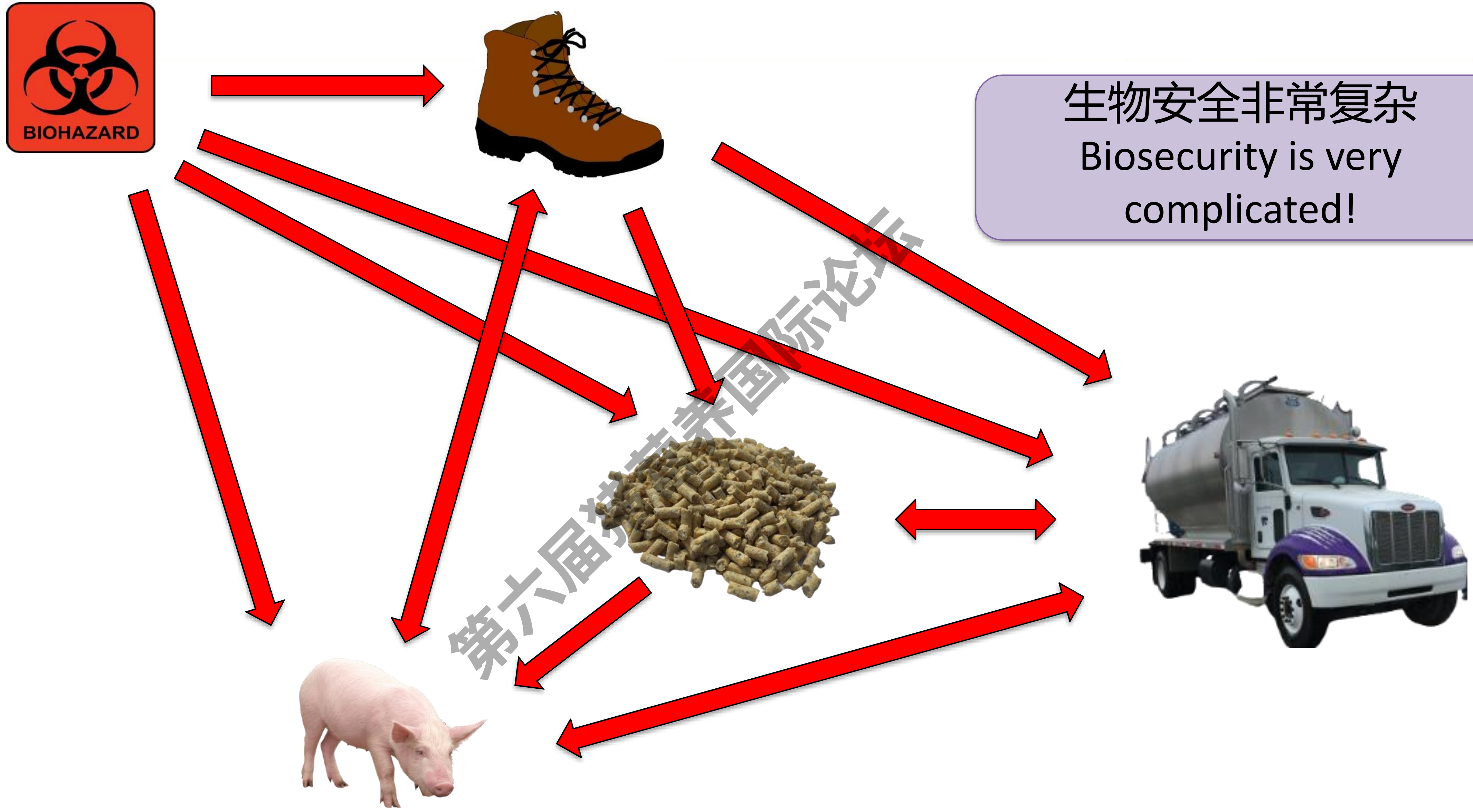
原料 Ingredient	口蹄疫 SVA (FMDV)	非洲猪瘟 ASFV	猪水疱病病毒 PSV (SVDV)	猪流行性腹泻病毒 PEDV	猫杯状病毒（疱疹病毒）FCV (VESV)	猪圆环病毒2型 PCV2	牛疱疹病毒I型 BHV-1 (PRV)	猪繁殖与呼吸综合征病毒 PRRSV 174	牛病毒性腹泻病毒（猪瘟病毒） BVDV (CSFV)	水疱性口炎病毒 VSV	犬瘟热病毒（雪腐镰刀菌烯醇） CDV (NiV)	流感病毒 IAV-S
常规豆粕 Soybean meal-Conventional	(+)	(+)	(+)	(+)	(+)	(-)	(+)	(+)	(-)	(-)	(-)	(-)
Soybean meal-Organic 有机豆粕	(-)	(+)	(+)	(+)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Soy oil cake 豆油饼	(+)	(+)	(+)	NT	(-)	(-)	(+)	(-)	(-)	(-)	(-)	(-)
DDGS 玉米酒糟粕	(+)	(-)	(-)	NT	(-)	(-)	(-)	(+)	(-)	(-)	(-)	(-)
Lysine 赖氨酸	(+)	(-)	(+)	(+)	(+)	(+)	(-)	(-)	(-)	(-)	(-)	(-)
Choline 胆碱	(+)	(+)	(-)	(+)	(-)	(+)	(-)	(-)	(-)	(-)	(-)	(-)
Vitamin D 维生素D	(+)	(-)	(+)	(+)	(-)	(+)	(-)	(-)	(-)	(-)	(-)	(-)
Moist cat food 猫湿粮	(+)	(+)	(+)	NT	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Moist dog food 犬湿粮	(+)	(+)	(+)	NT	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Dry dog food 犬干粮	(+)	(+)	(+)	NT	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Pork sausage casings 猪肉肠肠衣	(+)	(+)	(+)	NT	(+)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Complete feed (+ control) 全价料，正对照）	(+)	(+)	(+)	NT	(+)	(+)	(-)	(-)	(-)	(-)	(-)	(-)
Complete feed (- control) 全价料，负对照）	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Stock virus control 库存病毒对照组	(-)	(+)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)

Fig 4. Virus viability in feed ingredient from Batch 4 samples, inclusive of previous PEDV results [14]. A red-colored box with a (+) indicates that virus was recovered in a viable form from a specific ingredient, while a green-colored box with a (-) indicates that viable virus was not recovered by VI and/or swine bioassay. Finally, a blue-colored box with NT denotes that these ingredients were not used in this study and therefore, no results are available.

第 4 批样品中饲料成分的病毒活力，包括之前的 PEDV 结果。红色（＋）代表原料中有检查到活病毒活性片段，绿色(-)代表用生物检测方法未检测到活病毒活性片段，蓝色（NT）代表未检测到病毒片段。

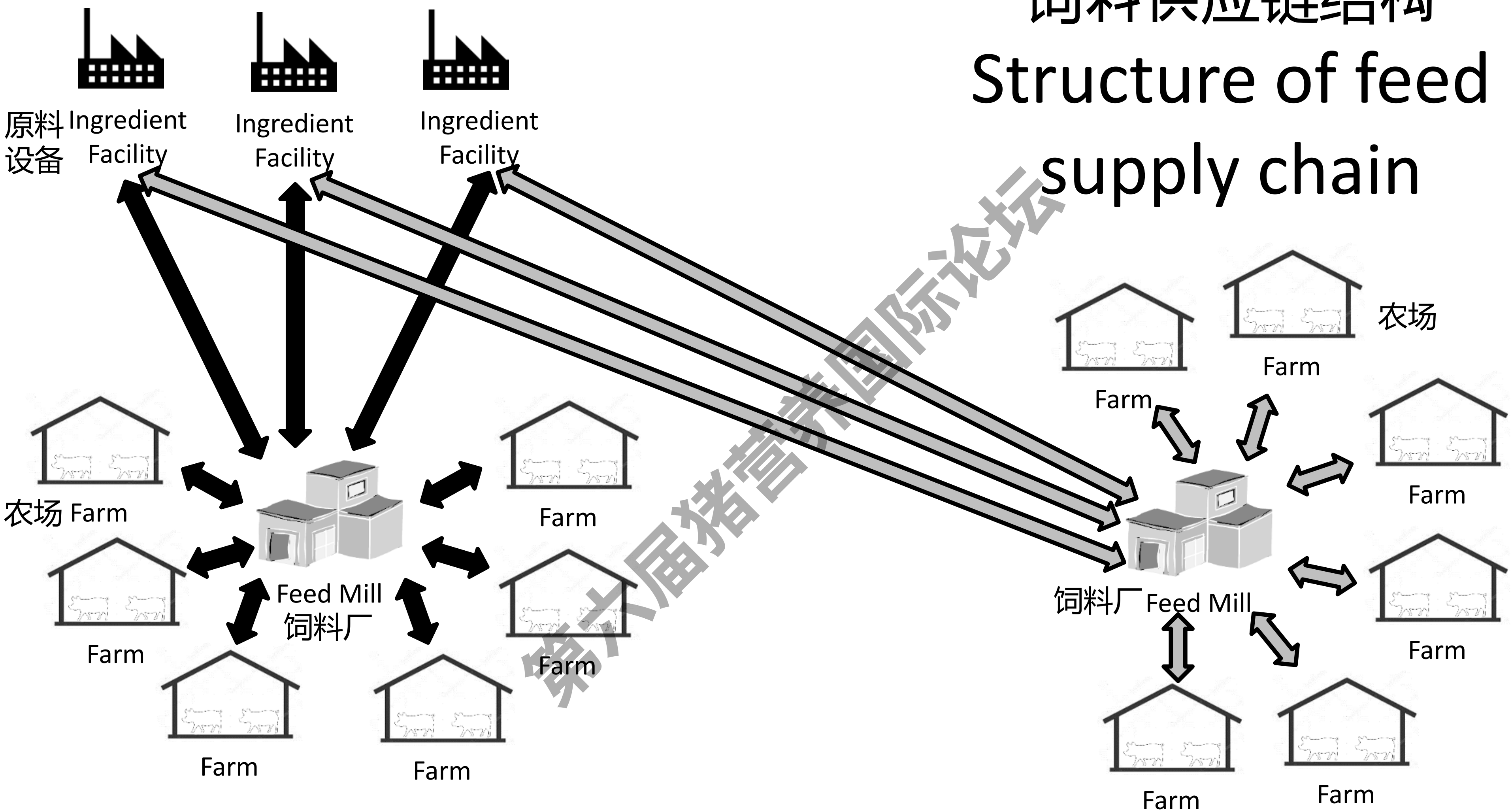
采用37d跨太平洋运输条件或30d跨大西洋运输条件获得的数据（仅限非洲猪瘟）

Data generated with 37 d trans-pacific shipping conditions or 30 d trans-Atlantic shipping conditions (ASFV only)



生物安全非常复杂
Biosecurity is very complicated!

饲料供应链结构
Structure of feed supply chain



解决饲料安全问题 Addressing Feed Safety

污染
Contamination

- 污染风险取决于 Risk of contamination depends on:
  - 地理因素Geographical considerations
    - 疾病爆发活跃的国家/区域 Countries/regions with active disease outbreaks
    - 患病猪位置相对于原料生产的位置 Location of pigs with disease relative to location of ingredient production
  - 农业操作规范 Agricultural practices
  - 包装 Packaging
    - 一次性袋子或手提袋与重复使用的手提袋或散装车 Single use bags or totes vs. re-used totes or bulk trailers

1. 了解原料的来源 Understand where ingredients are coming from
2. 生产、储存和运输过程的生物安全 BIOSECURITY during manufacture, storage, and delivery

污染
Contamination

研究伙伴关系Research partnership

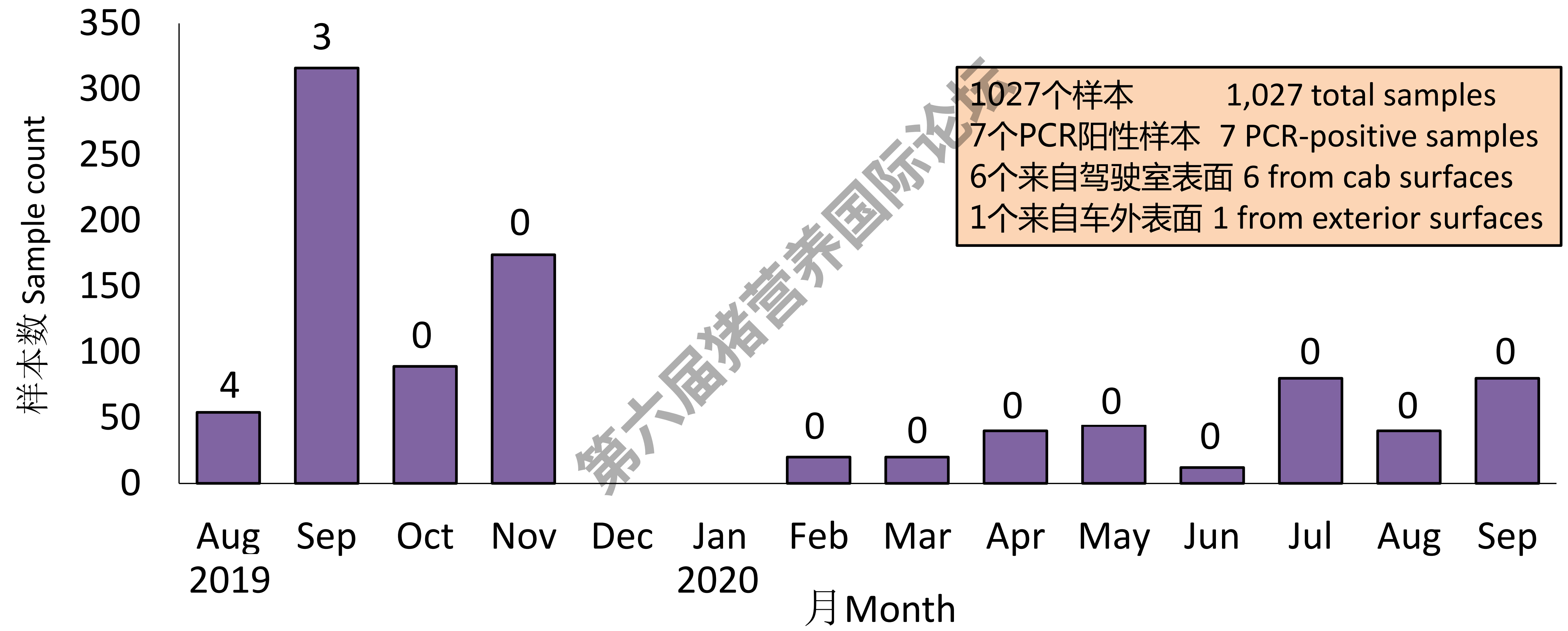
位于越南的生产系统 Production system located in Vietnam

目标:使用诊断测试了解ASFV在其生产系统中传播的风险 Goal: Use diagnostic testing capabilities to understand the risk of ASFV spread within their production system.

1. 饲料生产系统 Feed production system
    a. 饲料厂 Feed mill
    b. 原料和成品饲料 Ingredients and finished feed
    c. 饲料车 Feed trucks
2. 活体动物运输 Live animal transport
3. 上市动物转运中心Market animal transfer center

污染
Contamination

饲料运输车 Feed delivery vehicles



如何实现？How can this be accomplished?

Step 1:
去除有机物 Remove organic material

Step 2:
干燥 Dry

Step 3:
喷消毒剂 Apply disinfectant

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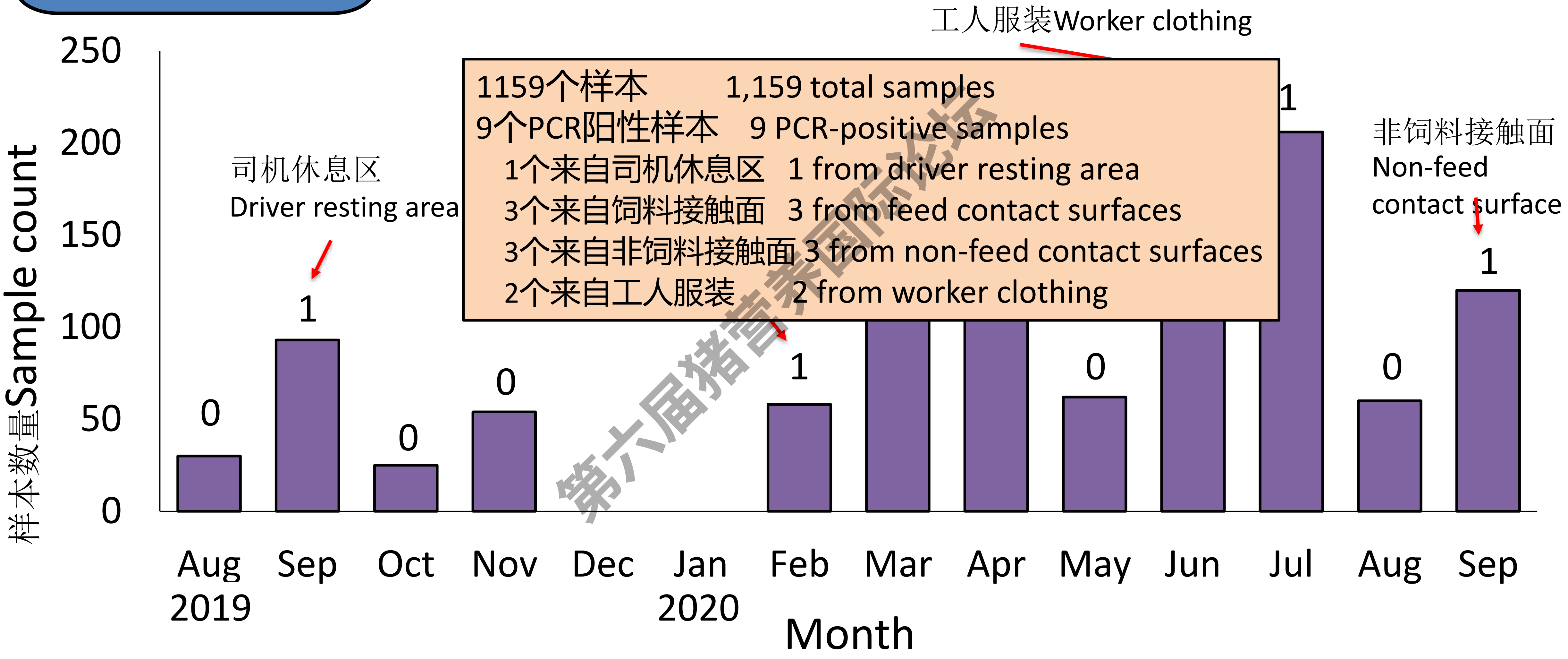
如何实现？How can this be accomplished?

避免这种情况 Avoid this

污染
Contamination

饲料厂表面 Feed mill surfaces

1159个样本　1,159 total samples
9个PCR阳性样本　9 PCR-positive samples
- 1个来自司机休息区　1 from driver resting area
- 3个来自饲料接触面　3 from feed contact surfaces
- 3个来自非饲料接触面 3 from non-feed contact surfaces
- 2个来自工人服装　2 from worker clothing



污染 Contamination

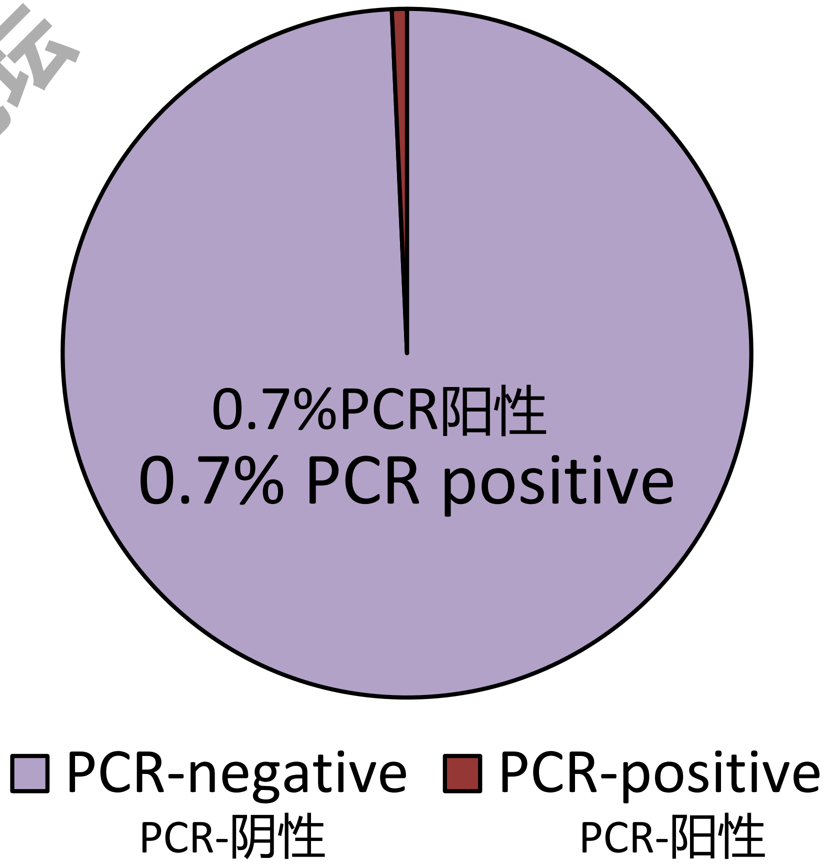
饲料和原料 Feed and ingredients

收集和分析142个样本 142 total samples collected and analyzed.

40个原理和水样 40 ingredient and water samples
102个全价料样品 102 complete feed samples

1个全价料样品PCR呈阳性 1 complete feed sample PCR positive

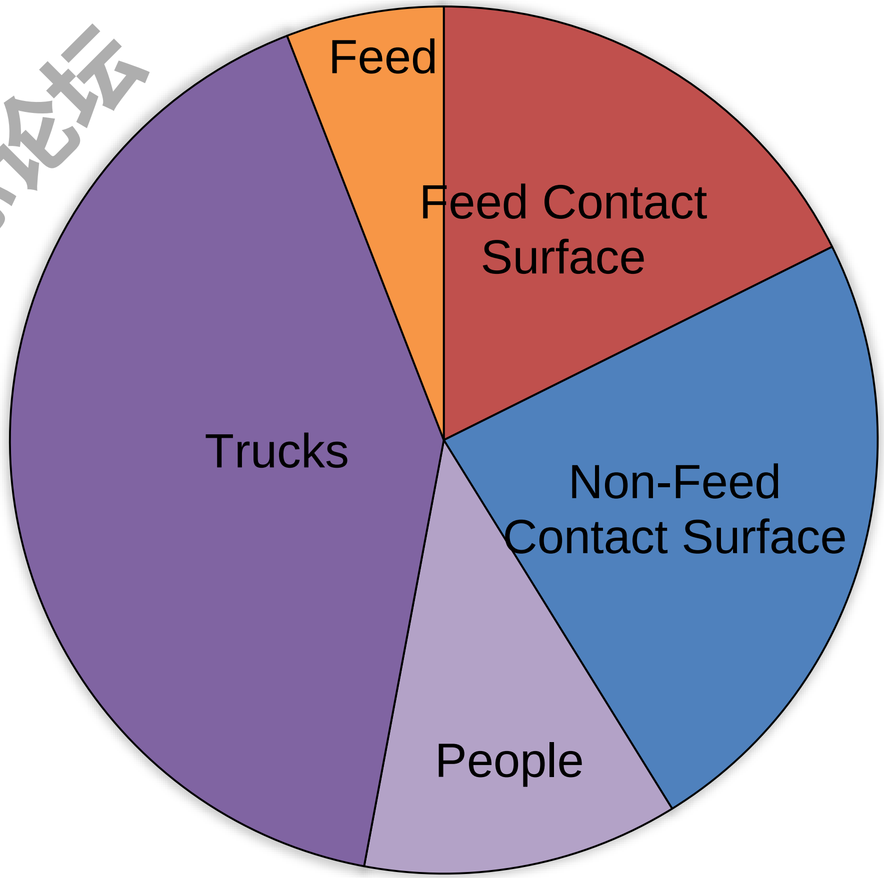
- 该批饲料未添加甲醛类产品 Batch of feed did not contain added formaldehyde-based product



污染
Contamination

哪里被污染？Where is the contamination at?

- 2328个饲料供应链样本中有17个（0.7%）经PCR检测出非洲猪瘟病毒DNA　17 of 2,328 samples (0.7%) from the feed supply chain contain ASFV DNA as determined by PCR
  - 3个饲料厂饲料接触表面 3 Feed-Contact Surfaces in Mill
  - 4个饲料厂非饲料接触表面 4 Non-Feed-Contact Surfaces in Mill
  - 2个饲料厂员工衣服 2 Employee clothing in Mill
  - 1个全价料 1 Complete Feed
  - 7个饲料车 7 Feed Trucks



关键发现:人和污染物非常重要！
Key finding: People and fomites are incredibly important!

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污染
Contamination

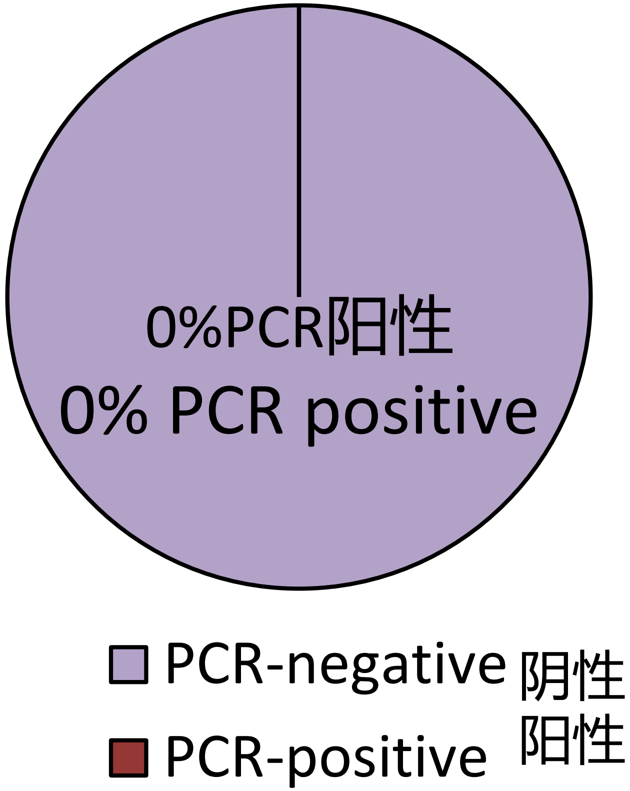
田间条件下饲料中地方性猪病毒的定量分析
Quantification of endemic swine viruses in feed under field conditions

<u>**目的：**</u>对美国中西部地区每年2个不同时间段的224份饲料样品进行病毒检测。<u>**Objective:**</u> Quantify the viral presence in 224 feed samples during two different times of year in Midwest US.

冬季-季节性病毒传播的风险更高。Winter – greater risk of seasonal viral transmission.
夏季-季节性病毒传播的风险降低。Summer – reduced risk of seasonal viral transmission.

<u>**诊断测试Diagnostic testing performed:**</u>
PRRSV PCR (Ct cutoff of 37)
PEDV/PDCoV/TGEV PCR (Ct cutoff of 36)

未检出PCR阳性样本 No PCR positive samples were detected



污染
Contamination

近期多项与饲料相关的诊断调查 Multiple recent feed-related diagnostic investigations

PEER REVIEWED　　CASE STUDY

了解饲料生产和运输在猪德尔塔冠状病毒调查中的作用

Understanding the role of feed manufacturing and delivery within a series of porcine deltacoronavirus investigations

C. Grace Elijah, DVM; Olivia L. Harrison; Allison K. Blomme; Jason C. Woodworth, PhD; Cassandra K. Jones, PhD; Chad B. Paulk, PhD; Jordan T. Gebhardt, DVM, PhD

Received: 6 May 2021 | Revised: 11 October 2021 | Accepted: 11 October 2021
DOI: 10.1111/tbed.14354
Transboundary and Emerging Diseases　WILEY

SPECIAL ISSUE ARTICLE

Feed or feed transport as a potential route for a porcine epidemic diarrhoea outbreak in a 10,000-sow breeding herd in Mexico

饲料或饲料运输作为墨西哥1万头母猪繁殖群中猪流行性腹泻暴发的潜在途径

Jorge Garrido-Mantilla[1] | Alicia Lara[2] | Ezequiel Guardado[1] | Jose Lopez[2] | Joel Nerem[1] | Gustavo Pizarro[1] | Jean Paul Cano[1]

Received: 3 May 2021 | Revised: 20 June 2021 | Accepted: 25 June 2021
DOI: 10.1111/tbed.14209
Transboundary and Emerging Diseases　WILEY

SPECIAL ISSUE ARTICLE

Interventions to reduce porcine epidemic diarrhea virus prevalence in feed in a Chinese swine production system: A case study

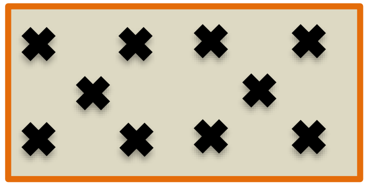
降低中国养猪生产系统饲料中猪流行性腹泻病毒流行的干预措施:案例研究

Fangzhou Wu[1] | Roger Cochrane[1] | Joseph Yaros[2] | Caixia Zhang[3] | Shih-Yi Tsai[3] | Gordon Spronk[2]

污染 Contamination

批次受污染后饲料中携带ASFV的风险 Risk of ASFV carryover in feed after contaminated batch

批次Batch	原料Ingredients
1	阴性Negative
2	接种ASFV Inoculated
3	阴性Negative
4	阴性Negative
5	阴性Negative
6	阴性Negative



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污染 Contamination

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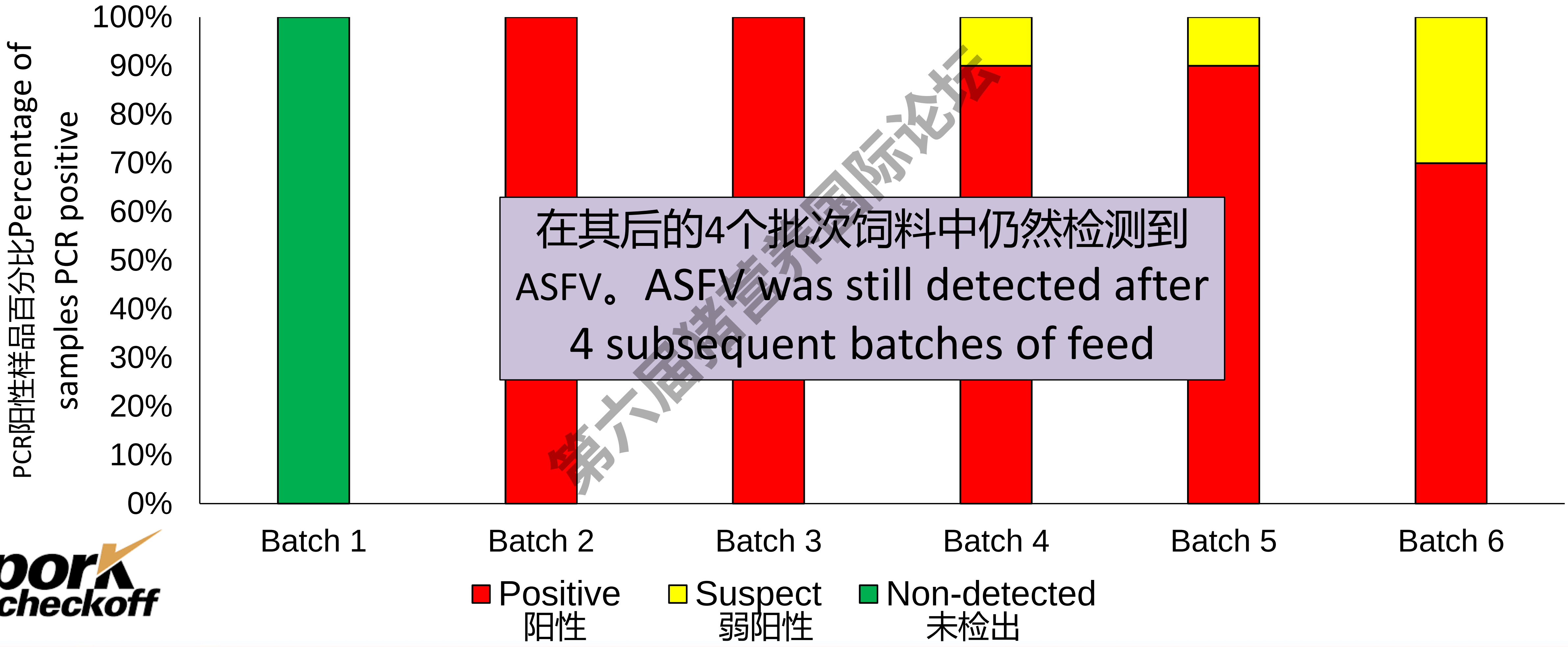

在其后的4个批次饲料中仍然检测到ASFV。ASFV was still detected after 4 subsequent batches of feed

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K·STATE Research and Extension

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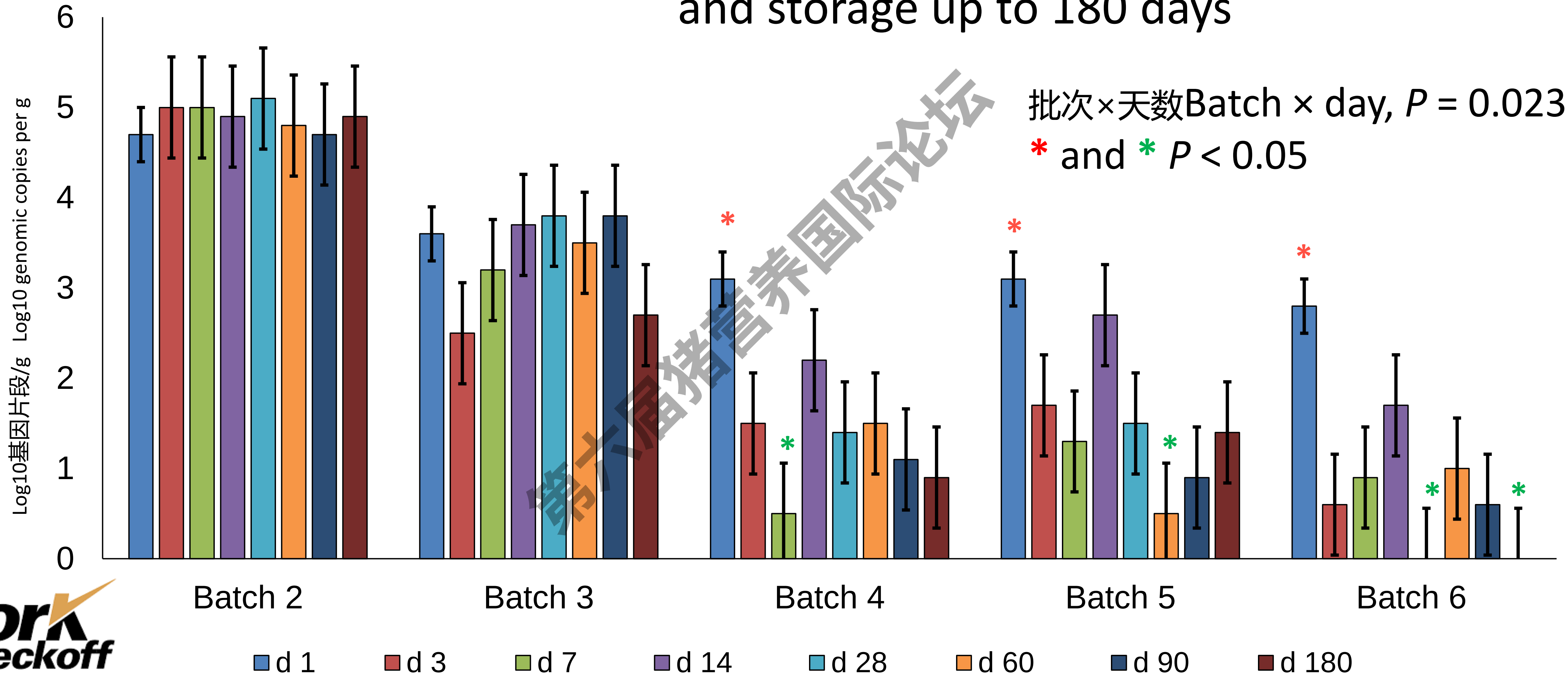
污染
Contamination

受污染批次和储存180天后，饲料中ASFV的残留风险
Risk of ASFV carryover in feed after contaminated batch and storage up to 180 days



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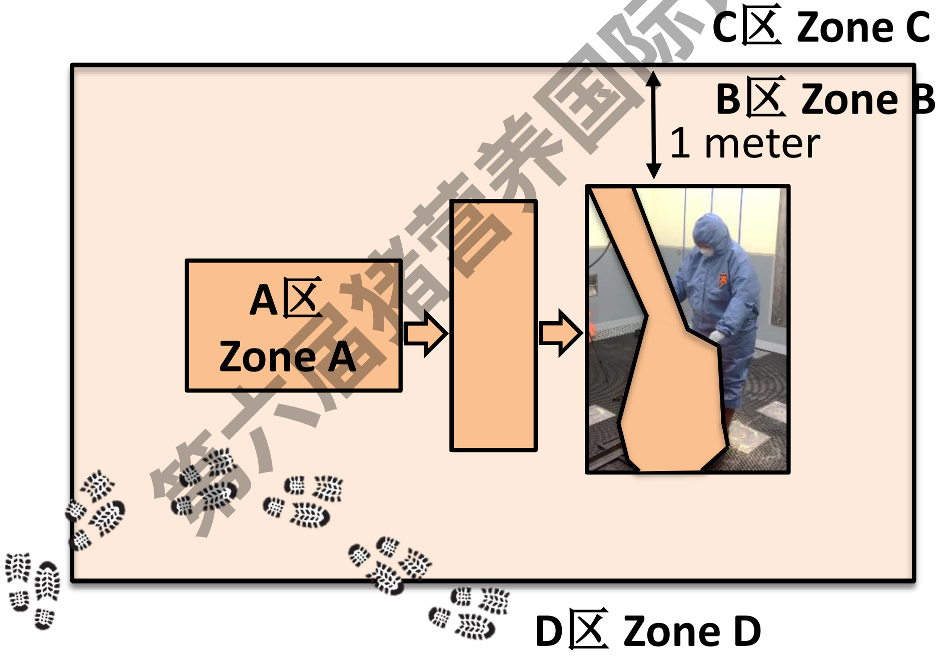
污染
Contamination

批次污染后ASFV在饲料表面和环境内残留的风险

Risk of ASFV carryover on feed surfaces and within environment after contaminated batch



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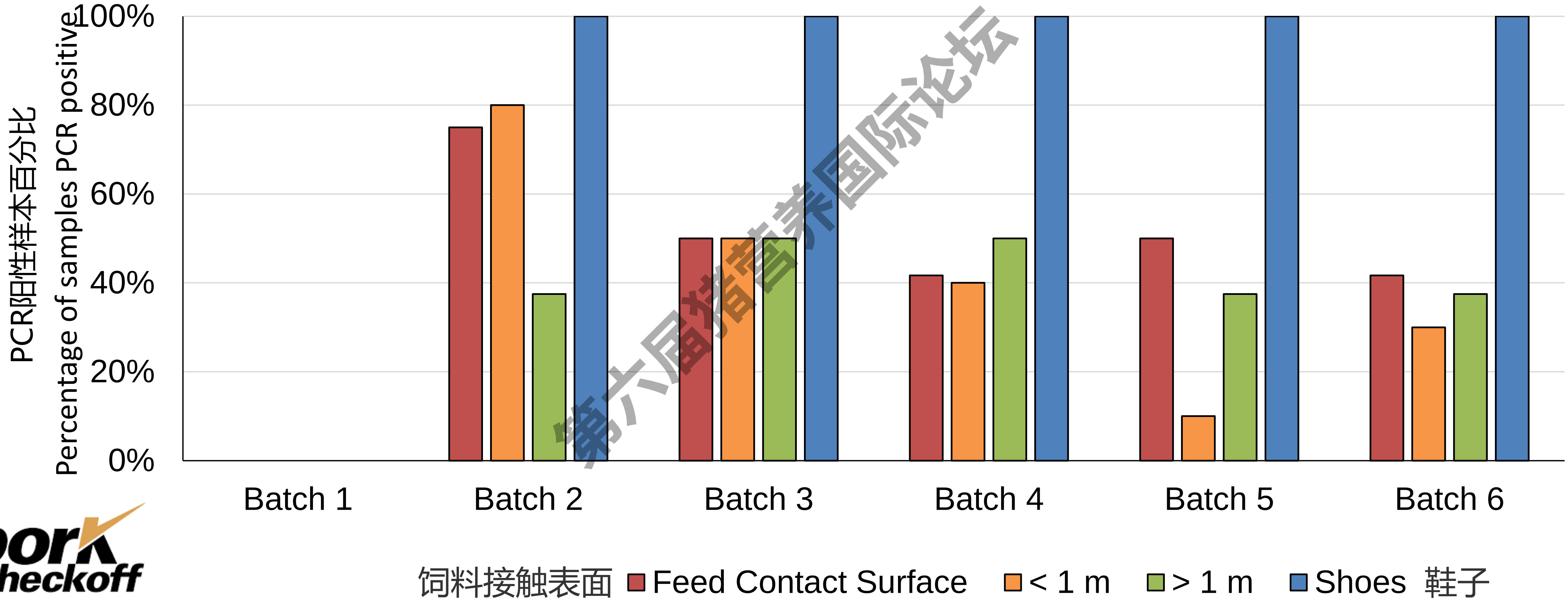
污染
Contamination

饲料批次受污染后，ASFV在饲料表面和环境内携带的风险
Risk of ASFV carryover on feed surfaces and within environment after contaminated batch



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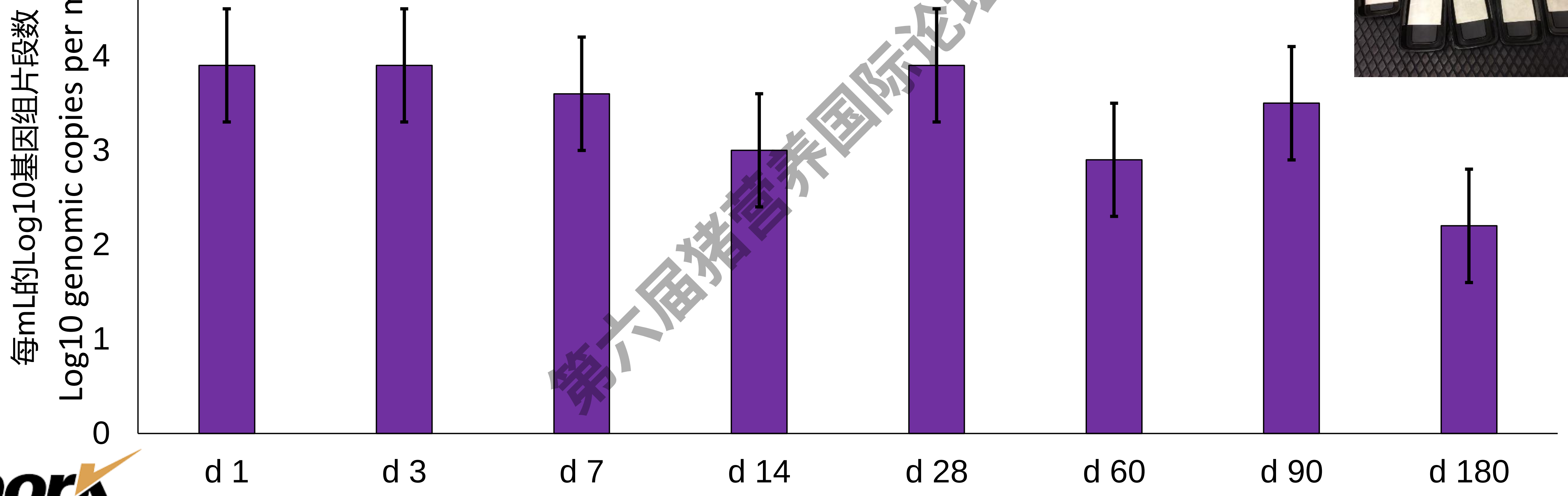
污染
Contamination

受污染批次和储存180天后，ASFV在环境表面携带的风险
Risk of ASFV carryover on environmental surfaces after contaminated batch and storage up to 180 days



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污染 Contamination

饲料批次受污染后，ASFV在饲料表面和环境内携带的风险
Risk of ASFV carryover on <u>feed surfaces and within environment</u> after contaminated batch

- 主要发现Key findings:
  - 在饲料厂内，ASFV与PEDV具有相似的特性 ASFV has similar characteristics to PEDV within a feed mill
    - 它无处不在 It goes everywhere!
  - 多批饲料通过设备后，可以检测到饲料和表面的污染 Contamination of feed and surfaces can be detected after multiple batches of feed pass through the equipment
  - 人是非常重要的考虑因素 People are extremely important to consider!





污染
Contamination

表面清洁/消毒原理Principles of surface cleaning/disinfection

1. 去除有机物 Removal of organic material
   – 使许多消毒剂灭活 Inactivates many disinfectants
2. 洗涤剂对去除有机物质很有用 Detergents can be useful to remove organic material
3. 冲洗残留物 Rinse off any residue
4. 自然晾干 Allow to dry
5. 然后应用消毒剂 Then apply disinfectant
   – 浓度和接触时间 Concentration & contact time

污染
Contamination

ASFV的表面消毒 Surface disinfection of ASFV

注册分类 Reg. type	EPA注册号 EPA Reg No	产品名 Product name	生产商 Manufacturer	活性成分 Active ingredient(s)	接触时间 Contact time	注册使用的场所(根据NPIRS，必须与集装箱上的标签一致) Registered use sites (according to NPIRS. Must confirm with label on container)	EPA网站-认证标签 Website for EPA-approved label
FIFRA section 3	39967-137	Virkon S	Lanxess Corporation	Sodium chloride Potassium peroxymonosulfate 氯化钠 钾 过氧硫酸钠	10 min	In/on animal feed equipment, livestock barns, livestock pens, livestock stalls, livestock stables, livestock equipment, hog farrowing pen premises, hog barns/houses/parlors/pens, animal quarters, animal feeding and watering equipment, animal transportation vehicles, animal equipment, agricultural premises, agricultural equipment, railroad boxcars, transportation vehicles, and human footwear	https://www3.epa.gov/pesticides/chem_search/ppls/039967-00137-20191011.pdf
FIFRA section 3	69470-37	Clearon Bleach Tablets	Clearon Corp	Sodium dichloro-s-triazinetrione 二氯三嗪三酮钠	30 min	In/on animal living quarters, farm premises, and shoe baths	https://www3.epa.gov/pesticides/chem_search/ppls/069470-00037-20160908.pdf
FIFRA section 3	71847-2	Klor-Kleen	Medentech Ltd.	Sodium dichloro-s-triazinetrione 二氯三嗪三酮钠	30 min	African swine fever virus in animal quarters and animal living quarters	https://www3.epa.gov/pesticides/chem_search/ppls/071847-00002-20130805.pdf
FIFRA section 3	71847-6	Klorsept	Medentech Ltd.	Sodium dichloro-s-triazinetrione 二氯三嗪三酮钠	30 min	In/on animal quarters, animal feeding/watering, animal equipment, and animal transportation vehicles	https://www3.epa.gov/pesticides/chem_search/ppls/071847-00006-20181227.pdf
FIFRA section 3	71847-7	Klorkleen 2	Medentech, Ltd.	Sodium dichloro-s-triazinetrione 二氯三嗪三酮钠	30 min	In/on livestock premises, animal feeding/watering equipment, animal equipment, animal transportation vehicles, farm premises, and shoe baths	https://www3.epa.gov/pesticides/chem_search/ppls/071847-00007-20180806.pdf

来源 Source:
https://www.aphis.usda.gov/animal_health/emergency_management/downloads/asf-virus-disinfectants.pdf

污染
Contamination

ASFV的表面消毒 Surface disinfection of ASFV

来源 Source:
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接上页 Continued:

注册分类 Reg. type	EPA注册号 EPA Reg No	产品名 Product name	生产商 Manufacturer	活性成分 Active ingredient(s)	接触时间 Contact time	注册使用的场所(根据NPIRS，必须与集装箱上的标签一致) Registered use sites (according to NPIRS. Must confirm with label on container)	EPA网站-认证标签 Website for EPA-approved label
FIFRA section 18	N/A	various	various	Sodium hypochlorite 次氯酸钠	15 min nonporous 不渗透的 30 min porous 可渗透的	Federal, State, or private indoor or outdoor use sites, such as agricultural, transportation, quarantine, and laboratory equipment and facilities; and, footwear/personal protective equipment.	https://www.aphis.usda.gov/animal_health/emergency_management/downloads/sodium-hypochlorite-label.pdf
FIFRA section 18	N/A	various	Archer Daniels Midland Co.	Citric acid 柠檬酸	15 min nonporous 不渗透的 30 min porous 可渗透的	Federal, State, or private indoor or outdoor use sites, such as agricultural and nonagricultural equipment and facilities; laboratory equipment and facilities; and footwear/personal protective equipment.	https://www.aphis.usda.gov/animal_health/emergency_management/downloads/19citricacid-exemption-label.pdf

污染
Contamination

来源 Source:
https://www.cfsph.iastate.edu/Disinfection/Assets/characteristics-of-selected-disinfectants.pdf

此表提供每种消毒剂化学分类的一般信息 This table provides general information for each disinfectant chemical class.

Characteristics of Selected Disinfectants
所选消毒剂的特性

抗菌活性可能因配方和浓度而异 Antimicrobial activity may vary with formulation and concentration.
Always read and follow the product label for proper preparation and application directions.
请务必阅读和遵循产品标签，以获得适当的准备和使用说明

消毒剂类别 Disinfectant Category	醇类 Alcohols	碱类 Alkalis	醛类 Aldehydes	氧化剂 Oxidizing Agents: Halogens 卤素 Chlorine 氯	氧化剂 Oxidizing Agents: Halogens 卤素 Iodine 碘	氧化剂 Oxidizing Agents: 超氧化物 Peroxygen Compounds	酚类 Phenols	Quaternary Ammonium Compounds 季胺类化合物
常见的活性成分 Common Active Ingredients	ethanol, isopropanol	calcium hydroxide, sodium carbonate, calcium oxide	formaldehyde, glutaraldehyde, ortho-phthalaldehyde,	sodium hypochlorite (bleach), calcium hypochlorite, chlorine dioxide	povidone-iodine	hydrogen peroxide/ accelerated HP, peracetic acid, potassium peroxymonosulfate	ortho-phenylphenol, orthobenzylpara-chlorophenol	benzalkonium chloride, alkyldimethyl ammonium chloride
作用机制 Mechanism of Action	Precipitates proteins; denatures lipids	Alters pH through hydroxyl ions; fat saponification	Denatures proteins; alkylates nucleic acids	Denatures proteins	Denatures proteins	Denature proteins and lipids	Denatures proteins; disrupts cell wall	Denatures proteins; binds phospholipids of cell membrane
特点 Characteristics	• Fast acting • Rapid evaporation • Leaves no residue • Can swell or harden rubber and plastics	• Slow acting • Affected by pH • Best at high temps • Corrosive to metals • Severe skin burns; mucous membrane irritation • Environmental hazard	• Slow acting • Affected by pH and temperature • Irritation of skin/ mucous membrane • Only use in well ventilated areas • Pungent odor • Noncorrosive	• Fast acting • Affected by pH • Frequent application • Inactivated by UV radiation • Corrodes metals, rubber, fabrics, • Mucous membrane irritation	• Stable in storage • Affected by pH • Requires frequent application • Corrosive • Stains clothes and treated surfaces	• Fast acting • May damage some metals (e.g., lead, copper, brass, zinc) • Powdered form may cause mucous membrane irritation • Low toxicity at lower concentrations • Environmentally friendly	• Can leave residual film on surfaces • Can damage rubber, plastic; non-corrosive • Stable in storage • Irritation to skin and eyes	• Stable in storage • Best at neutral or alkaline pH • Effective at high temps • High concentrations corrosive to metals • Irritation to skin, eyes, and respiratory tract
注意事项 Precautions	Flammable	Very caustic	Formaldehyde has carcinogenic potential	Toxic gas released if mixed with strong acids or ammonia			May be toxic to animals, especially cats and pigs	
杀菌 Bactericidal	+	+	+	+	+	+	+	+
杀病毒 Virucidal	±[a]	+	±	+	+	+	+	+ Enveloped
杀真菌 Fungicidal	+	+	+	+	+	±	+	+
杀结核菌 Tuberculocidal	+	±	+	+	+	±	+	−
杀孢子 Sporicidal	−	+	+	+	±	+	−	+
影响效率的因素 Factors Affecting Effectiveness	Inactivated by organic matter	Variable	Inactivated by organic matter, hard water, soaps and detergents	Rapidly inactivated by organic matter	Rapidly inactivated by organic matter	Effective in presence of organic matter, hard water, soaps, and detergents	Effective in presence of organic matter, hard water, soaps,and detergents	Inactivated by organic matter, hard water, soaps and anionic detergents

+ = effective 有效的; ± = variable or limited activity 可变或有限的活性; − = not effective 无效的

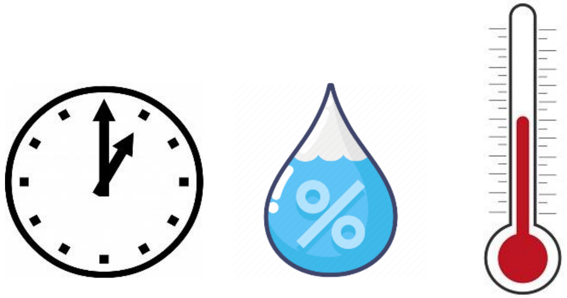
a - slow acting against nonenveloped viruses (e.g., norovirus)
a-对非包膜病毒(如诺如病毒)作用缓慢

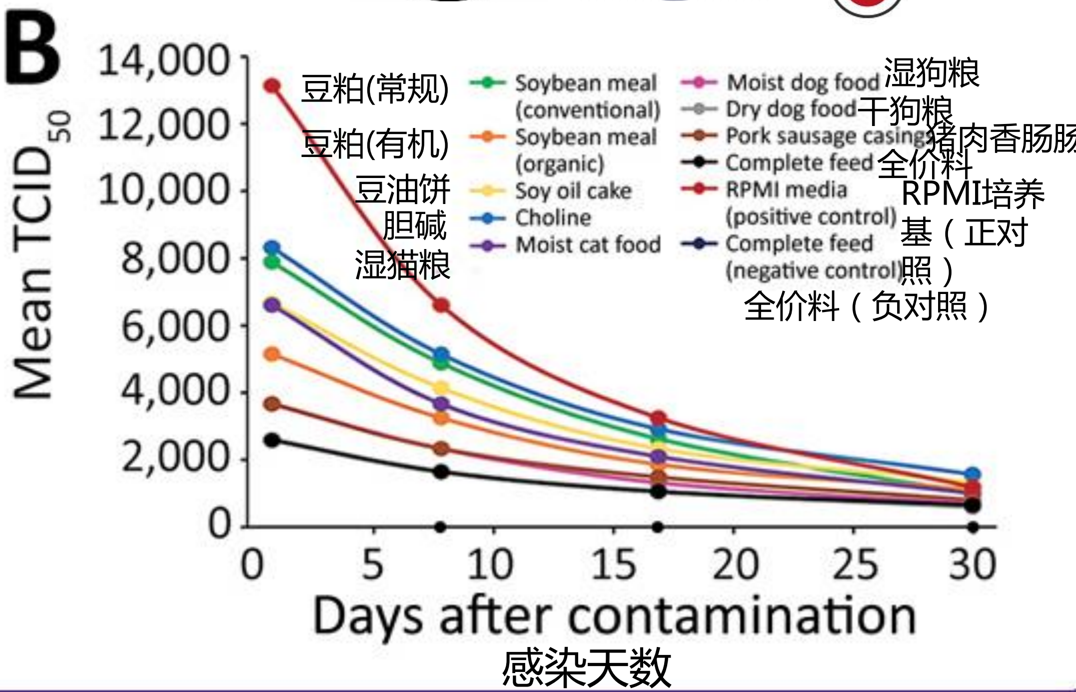
References: Fraise AP, Lambert PA, Maillard J-Y. Russell, Hugo & Ayliffe's Principles and Practice of Disinfection, Preservation and Sterilization, 5th ed. 2013. Ames, IA: Wiley-Blackwell; McDonnell GE. Antisepsis, Disinfection, and Sterilization: Types, Action, and Resistance. 2007. ASM Press, Washington DC. Rutala WA, Weber DJ, Healthcare Infection Control Practices Advisory Committee (HICPAC). 2008. Guideline for disinfection and sterilization in healthcare facilities. Available at: http://www.cdc.gov/hicpac/Disinfection_Sterilization/toc.html; Quinn PJ, Markey FC et al. (eds). Veterinary Microbiology and Microbial Disease. 2nd ed. 2011. West Sussex, UK: Wiley-Blackwell, pp 851-889.

病原体存活
Pathogen survival

病毒随时间的自然衰减 Natural decay of viruses over time

- 病原体必须在表面存活才能引起感染 Pathogen has to survive on surface to cause infection
  - 病毒在没有宿主的情况下不会自我繁殖 Viruses do not replicate outside of host
  - 随着时间的推移自然衰减(失去传染性) Naturally decay over time (lose infectivity)
    - 时间，温度，湿度，环境Time, temperature, humidity, environment
- 最大的存活宿主：Greatest survival in:
  - 胆碱 Choline
  - 豆粕 Soybean meal
  - 豆油饼 Soy oil cake





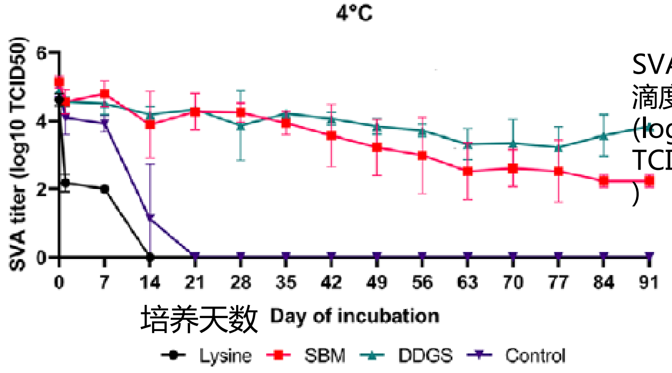
Stoian et al., 2019

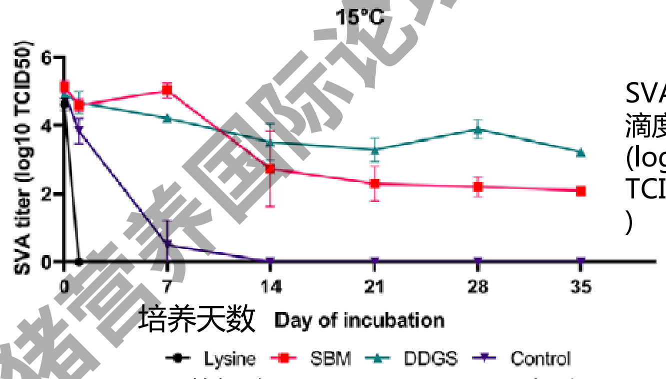
病原体存活
Pathogen survival

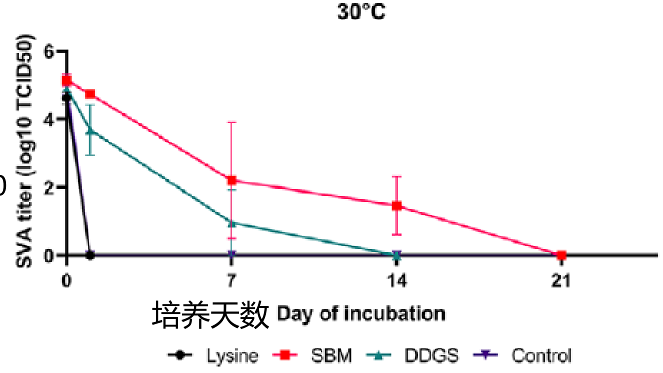
塞内卡病毒A在饲料原料中的稳定性随时间的变化 Stability of Senecavirus A in feed ingredients over time

原料样品接种SVA (10^5 病毒滴度)，在4、15或30℃保存 Ingredient samples inoculated with SVA (10^5 $TCID_{50}$) and stored at 4, 15, or 30 C

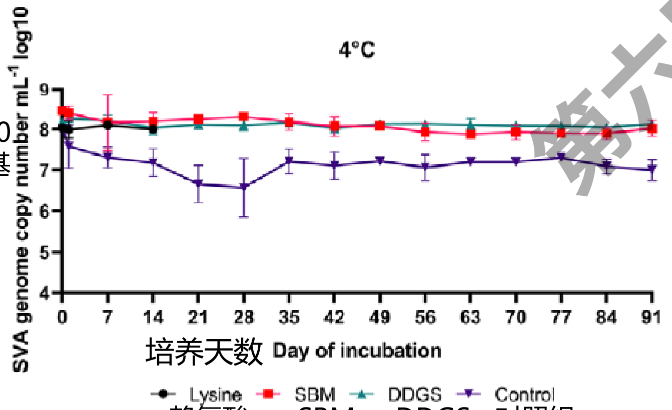
活病毒
Viable virus

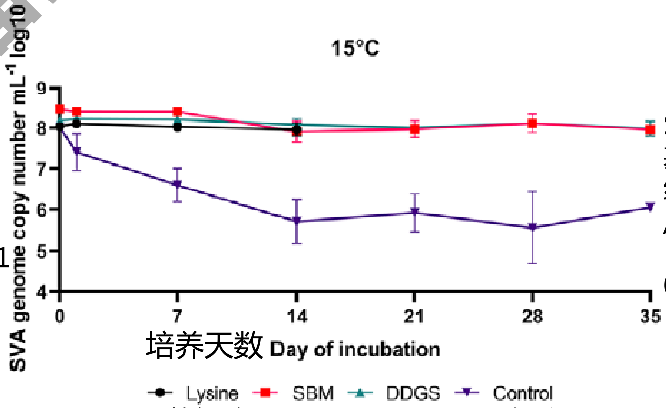


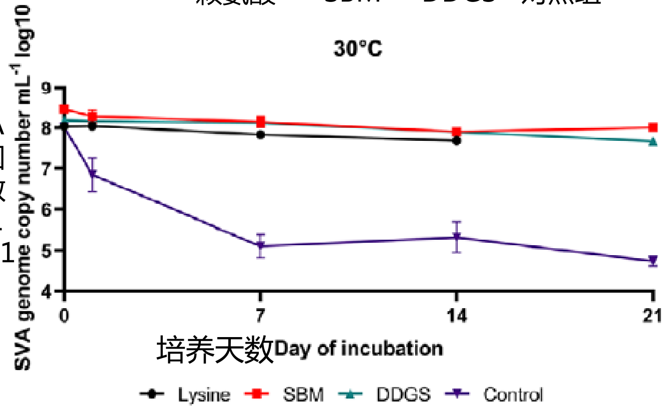




遗传物质
Genetic material





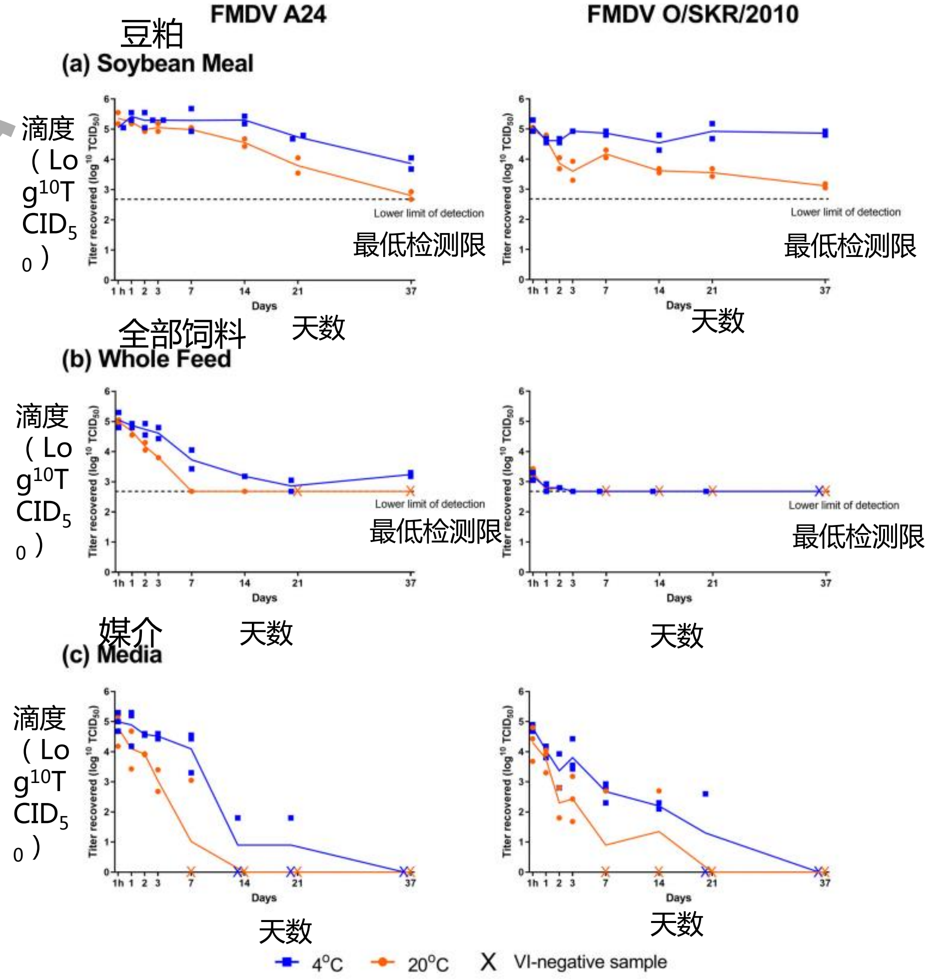


Caserta et al., 2022

病原体存活 Pathogen survival

口蹄疫病毒在饲料和豆粕中随时间的稳定性 Stability of FMDV in feed and soybean meal over time

- 接种两株FMDV (10^5 $TCID_{50}$)和感染FMDV的样品随时间的变化。Samples inoculated with two strains of FMDV (10^5 $TCID_{50}$) and infectious FMDV measured over time.
- 在2个温度下储存 Stored at 2 temperatures:
  - 4和20℃ 4 C and 20 C
- 随着时间的推移，观察到的豆粕和全价饲料之间的差异。Natural decay over time observed, with differences observed between soybean mean and complete feed.
  - 随着时间的推移，豆粕中存活的FMDV数量会增加。Amount of viable FMDV greater over time in soybean meal.
  - 与4℃相比，20℃时的衰减的速度更快 Rate of decay more rapid at 20 C compared to 4 C

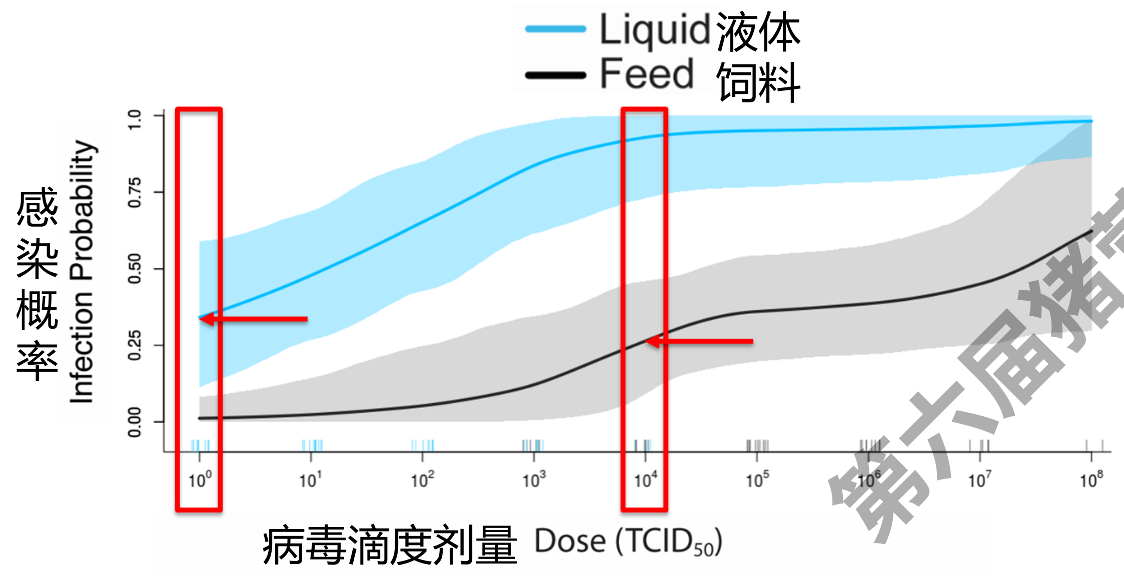


Stenfeldt et al., 2022

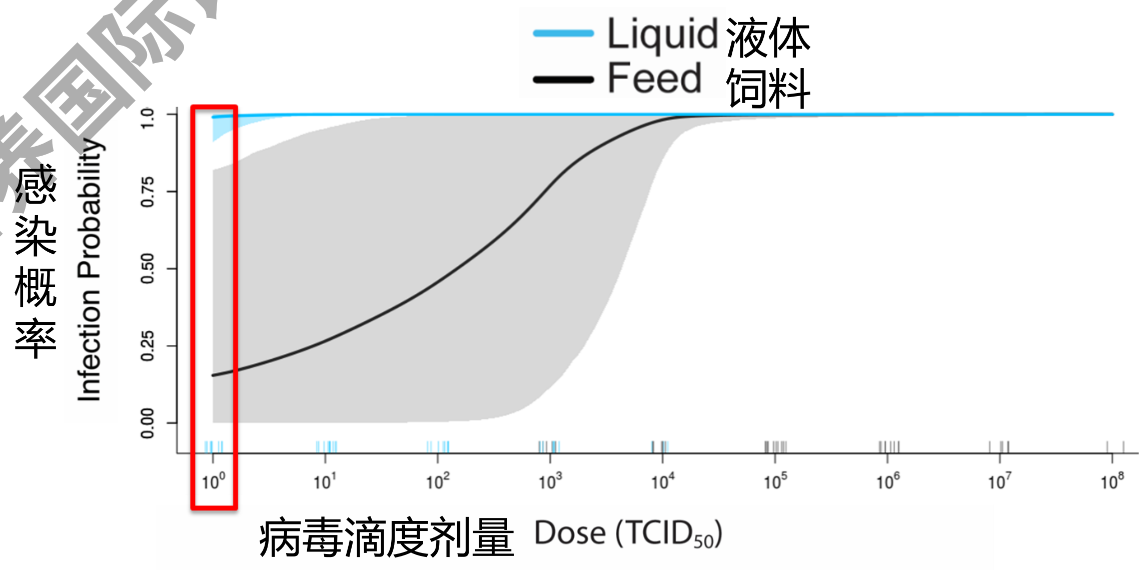
足剂量暴露
Exposure at sufficient dose

接种饲料引起的感染风险-非洲猪瘟病毒 Risk of inoculated feed causing infection - ASFV

单次暴露一种动物
Single Exposure to a Single Animal
(100 g × 1 time)



多次暴露同一动物
Multiple Exposures to a Single Animal
(100 g × 20 times)



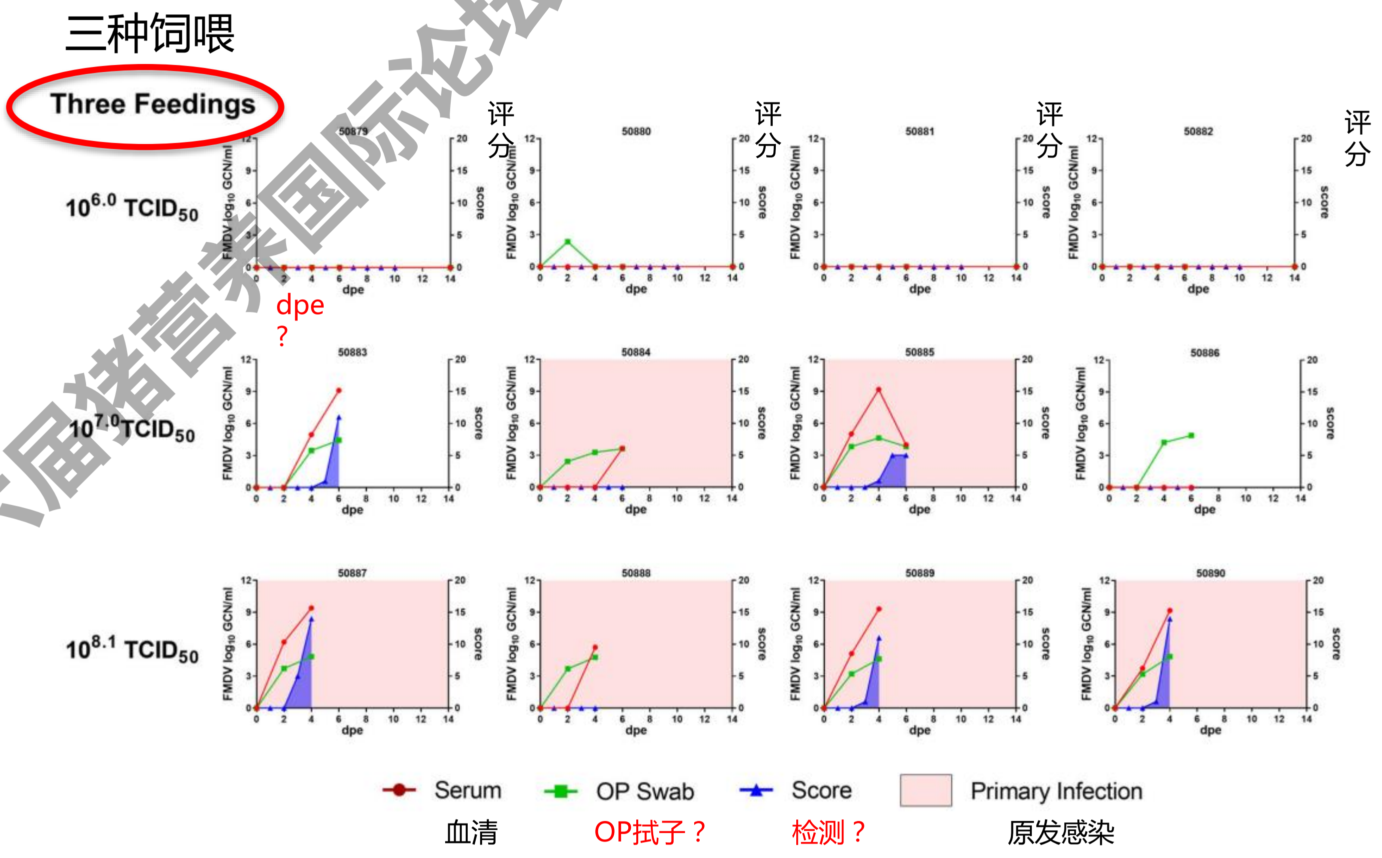
多次暴露会增加感染风险Multiple exposures increases risk of infection

Niederwerder et al., 2019

足剂量暴露 Exposure at sufficient dose

接种饲料引起的感染风险- 口蹄疫病毒 Risk of inoculated feed causing infection - FMDV

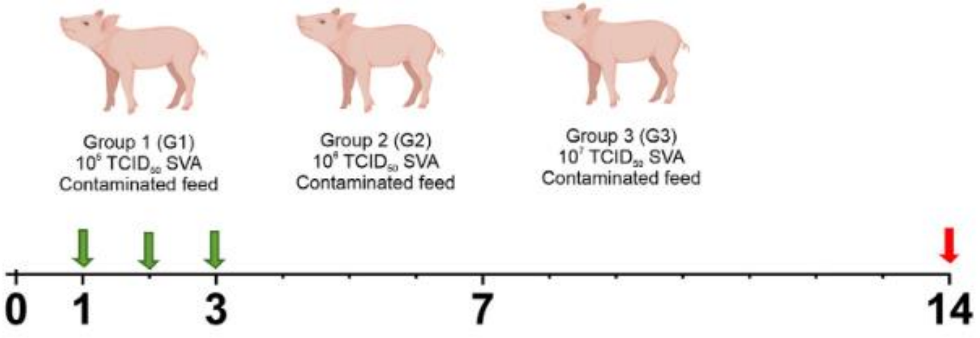
- 饲喂单剂量$10^{4.4}$ ~ $10^{7.2}$的FMDV的猪没有被感染。No pigs fed a single dose of FMDV from $10^{4.4}$ to $10^{7.2}$ were infected.
- 被FMDV污染的饲料，如果以足够高的水平提供多次饲喂，可导致感染。Feed contaminated with FMDV can cause infection if provided at high enough levels with multiple feedings.



Stenfeldt et al., 2022

足剂量暴露
Exposure at sufficient dose

接种饲料引起的感染风险- 塞内卡病毒 Risk of inoculated feed causing infection - SVA



- 连续饲喂接种饲料3天 Pigs fed inoculated feed for 3 consecutive days
- 提供三种不同的剂量Doses provided to 3 different groups:
  - 10^5, 10^6, and 10^7 TCID$_{50}$/50g饲料 10^5, 10^6, and 10^7 TCID$_{50}$ per 50 gram feed
- 饲喂10^5 TCID$_{50}$/50g的饲料会导致感染 Consumption of 10^5 TCID$_{50}$ per 50 grams of feed resulted in infection.

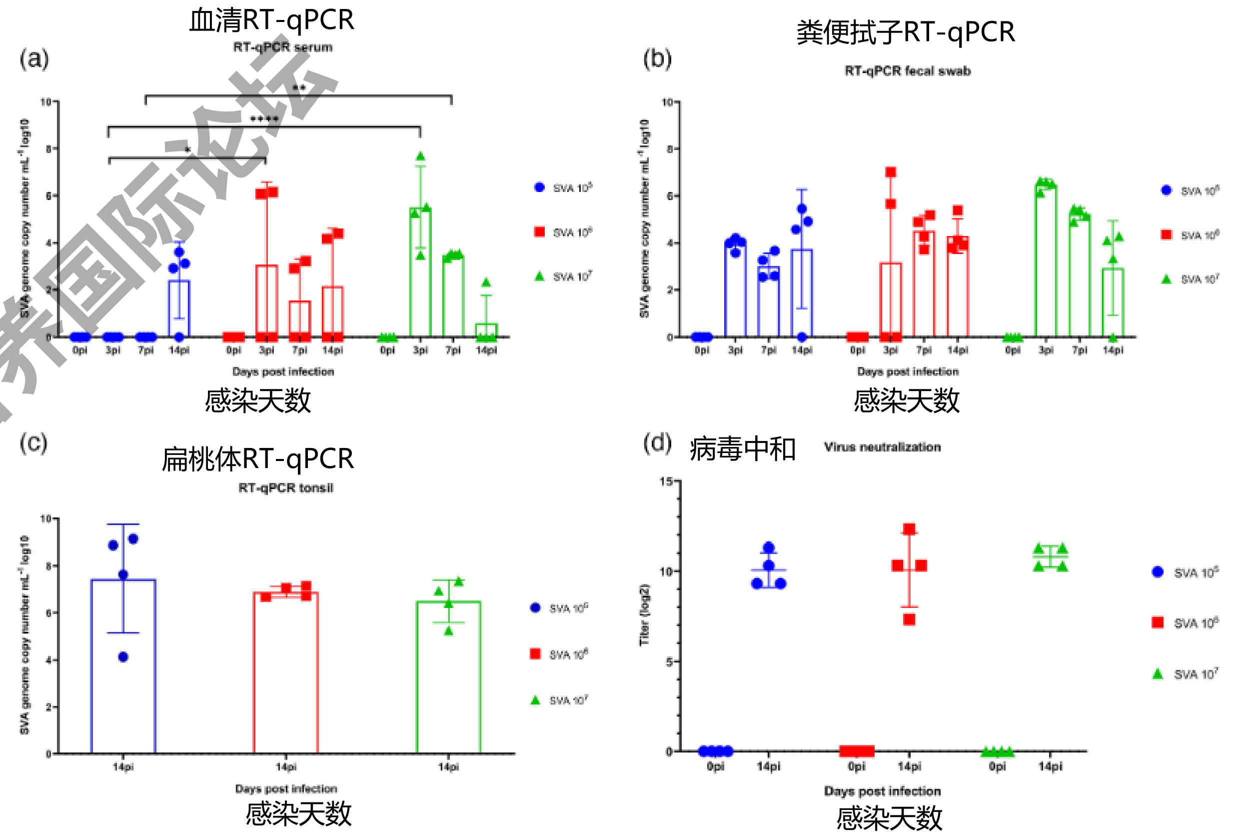


FIGURE 4 Viral load and neutralizing antibodies levels after bioassay with piglets. Viral load in serum (a), faecal swabs (b) and tonsil (c) were determined by RT-qPCR and neutralizing antibodies levels were determined by virus neutralization assay (d) after the consumption of feed contaminated with 10^5, 10^6 and 10^7 TCID$_{50}$ of SVA per 50 g of feed. Asterisks indicate significant differences: *$P = .0221$; **$P = .0083$; ****$P < 0.0001$

图4. 仔猪活检后的病毒载量和中和抗体水平。通过RT-qPCR检测血清(a)、粪便拭子(b)和扁桃体(c)的病毒载量，通过病毒中和试验(d)检测每50g饲料中10^5、10^6和10^7 TCID50的SVA感染后的中和抗体水平。*表示差异显著:*P=0.0221， **P=0.0083， ****P<0.0001

Caserta et al., 2022

足剂量暴露
Exposure at sufficient dose

接种饲料引起的感染风险- 猪流行性腹泻病毒 Risk of inoculated feed causing infection - PEDV

- 将PEDV连续接种到饲料中。 PEDV serially inoculated into feed.
- 如果饲料样品接种56 $TCID_{50}$/g或更高，猪就会被感染。Pigs became infected if feed samples were inoculated with 56 $TCID_{50}$/g or greater.

表1 - RT-qPCR检测10日龄猪(每处理3头猪)饲料、粪便拭子标本和盲肠内容物中PEDV的Ct值。

Table 1—The Ct values for an RT-qPCR assay to detect PEDV in feed fed to and fecal swab specimens and cecal contents obtained from 10-day-old pigs (3 pigs/treatment).

饲料中的PEDV PEDV in feed ($TCID_{50}$/g)*	组织培养基 Tissue culture medium	饲料 Feed	粪便拭子样本 Fecal swab specimens 0天 Day 0	2天 Day 2	4天 Day 4	6天 Day 6	7天 Day 7	盲肠内容物 Cecal contents†
无病毒饲料 Virus-free feed	Neg 阴性	Neg	Neg	Neg	Neg	Neg	Neg	Neg
5.6 X 10^{-4}	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg
5.6 X 10^{-3}	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg
5.6 X 10^{-2}	38.0	Neg	Neg	Neg	Neg	Neg	Neg	Neg
5.6 X 10^{-1}	34.3	Neg	Neg	Neg	Neg	Neg	Neg	Neg
5.6 X 10^{0}	30.6	Neg	Neg	Neg	Neg	Neg	Neg	Neg
5.6 X 10^{1}	27.4	37.1	Neg	33.2	20.7	19.8	25.3	23.1
5.6 X 10^{2}	24.3	33.6	Neg	27.3	22.2	21.3	24.2	26.5
5.6 X 10^{3}	20.7	29.5	Neg	30.7	22.4	21.2	25.2	24.0
5.6 X 10^{4}	16.6	27.0	Neg	27.4	21.0	21.9	25.2	25.4
SEM	ND	0.3	NA	1.9	1.9	2.1	2.8	2.4

Schumacher et al., 2016

足剂量暴露
Exposure at sufficient dose

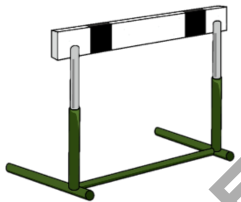
饲料作为疾病的媒介 Feed as vector for disease

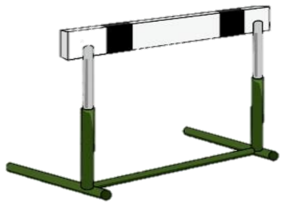
- 对于PEDV，来自一头急性感染猪的1克粪便可以污染500吨的饲料，每克粪便都具有传染性　For PEDV, 1 gram of feces from an acutely infected pig can contaminate 500 tonnes of feed – with EACH GRAM being infective.

Schumacher et al., 2016

饲料生物安全:防止病原体通过饲料供应链转移的障碍

Feed Biosecurity:
Hurdles to Prevent Pathogen Transfer through feed supply chain





预防Prevention

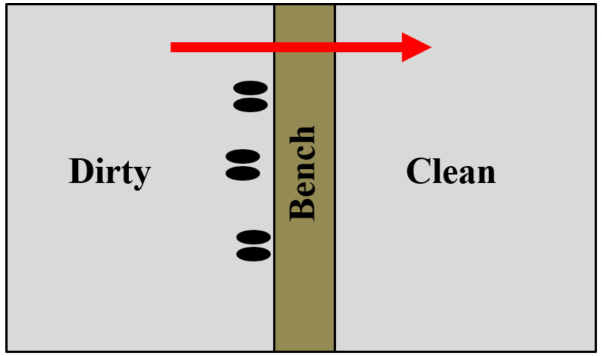
- 原料来源Ingredient sourcing
- 生物安全Biosecurity

干预Intervention

- 时间点 Point-in-time
- 残　留 Residual

预防
Prevention

- 将生物安全扩展到饲料加工厂，以限制来自卡车和人的感染 Extend biosecurity to feed mills to limit contamination from trucks and people
  - 使用接收垫/漏斗Use receiving mats/funnels
  - 限制人员活动 Restrict movement of personnel
    - 自己的员工卸货Use your own employees to unload
  - 实施员工流动控制 Implement control of employee movement
    - 物理屏障，浸脚消毒池，分区 Physical barriers, foot baths, zoning
- 对卡车等物体表面进行消毒 Disinfection of trucks and other surfaces

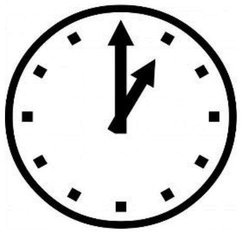


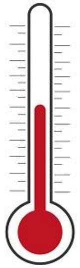
干预
Intervention

干预措施
Intervention approaches

即时控制Point-in-Time

– 容易被再次污染
Susceptible to recontamination
- 时间 Time
- 辐照 Irradiation
- 热处理 Thermal processing





持续控制Residual

– 残留活性有助于防止被再次污染
Have some level of residual activity to help combat possible recontamination
- 酸和碱 Acids and alkalis
- 精油 Essential oils
- 甲醛类产品 Formaldehyde-based products
- 中链脂肪酸 Medium chain fatty acids

干预
Intervention

即时控制：储存时间
Point in time: Holding time

- 已经得到了基于半衰期估计值的推荐储存时间
  Based on half-life estimates, recommended holding times have been established
  1. 温度Temperature
  2. 原料种类Ingredient matrix
- 进一步获得更准确的半衰期估计值
  Half-life estimates improving

降解99.9% A型塞内卡病毒(SVA)所需的平均储存时间

	Mean Holding Time for 99.99% SVA Degradation			
		Days at 4°C (39.6°F)	Days at 15°C (59°F)	Days at 30°C (86°F)
普通豆粕	Conventional SBM	143 days	52 days	26 days
DDGS	DDGS	494 days	182 days	26 days
维生素D	Vitamin D	39 days	26 days	26 days
赖氨酸	Lysine	78 days	13 days	13 days

54℉时，降解99.9% 非洲猪瘟病毒(ASF)所需的平均储存时间

	Mean Holding Time for 99.99% ASF Degradation at 54°F Avg.[3]			
		Average 平均值	95% Confidence Interval - Lower 95%置信区间下限	95% Confidence Interval – Higher 95%置信区间上限
普通豆粕	Conventional SBM	125 days	113 days	135 days
有机豆粕	Organic SBM	168 days	150 days	186 days
胆碱	Choline	155 days	142 days	168 days

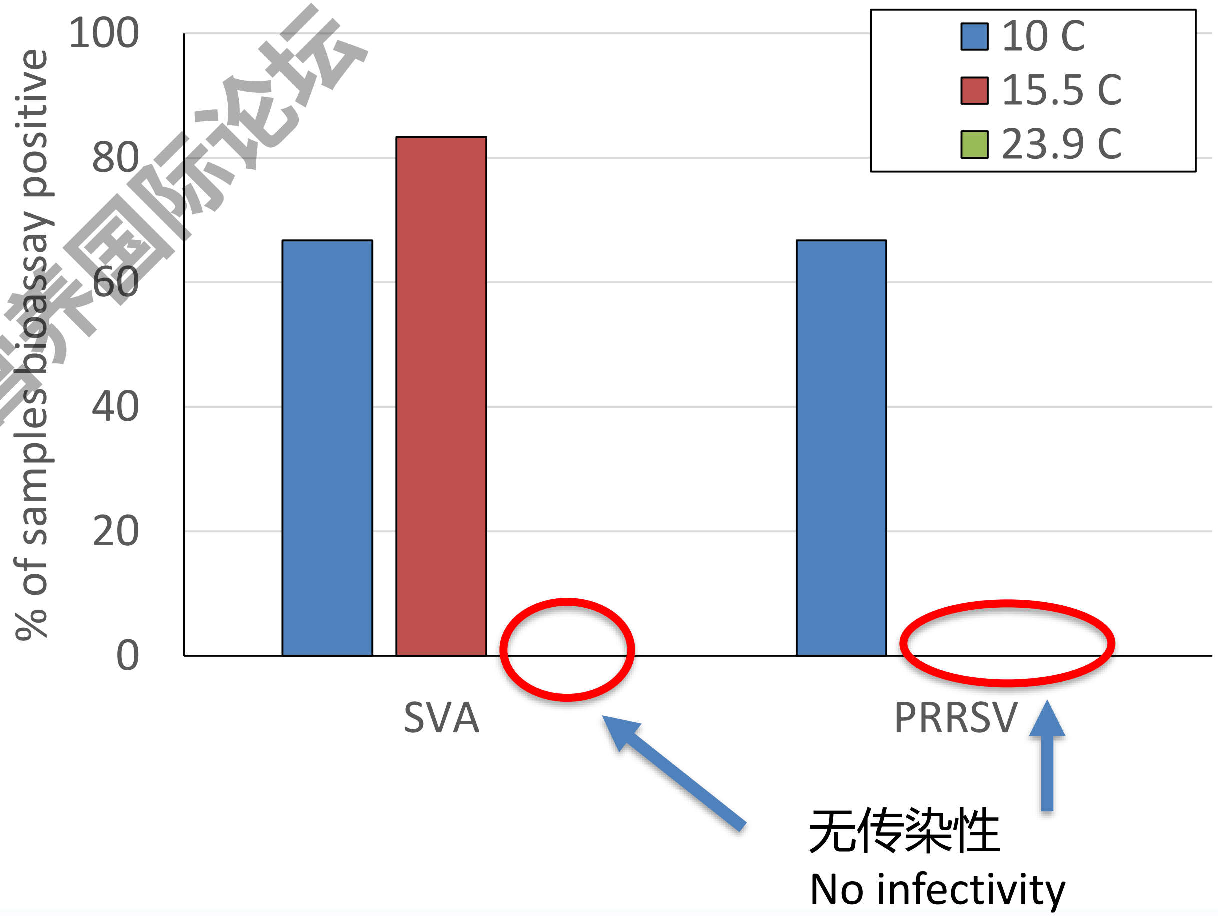
AMERICAN ASSOCIATION OF SWINE VETERINARIANS
SHIC Swine Health Information Center
pork checkoff
NATIONAL PORK PRODUCERS COUNCIL

https://www.swinehealth.org/wp-content/uploads/2020/02/Holding-Time-Calculations-for-Feed-Ingredients-to-Mitigate-Virus-Transmission-Print-02.04.20.pdf

干预
Intervention

储存时间：近期研究数据
Holding time: Recent data

- 1吨袋豆粕接种蓝耳病病毒（PRRS）或SVA病毒
  1 tonne totes of soybean meal inoculated with PRRSV or SVA.
- 在10、15.5、23.9摄氏度下储存30天
  Stored for 30 d at 10, 15.5 or 23.9 C.
- 23.9℃下储存30天后无传染性
  No infectivity after 30 d storage at 23.9 C.



即时控制：猪流行性腹泻病毒（PEDV）热处理

Point in time: PEDV thermal processing

	Feed	0 dpi	2 dpi	4 dpi	6 dpi	7 dpi	7 dpi Cecum
No PEDV	0	0	0	0	0	0	0
38°C	9/9	0	1/9	3/9	3/9	3/9	3/9
46°C	9/9	0	3/9	3/9	3/9	3/9	3/9
54°C	9/9	0	0	0	0	0	0
63°C	8/9	0	0	0	0	0	0
71°C	8/9	0	0	0	0	0	0

日粮制粒温度 > 54°C后无传染性

No infectivity in diets pelleted > 54°C

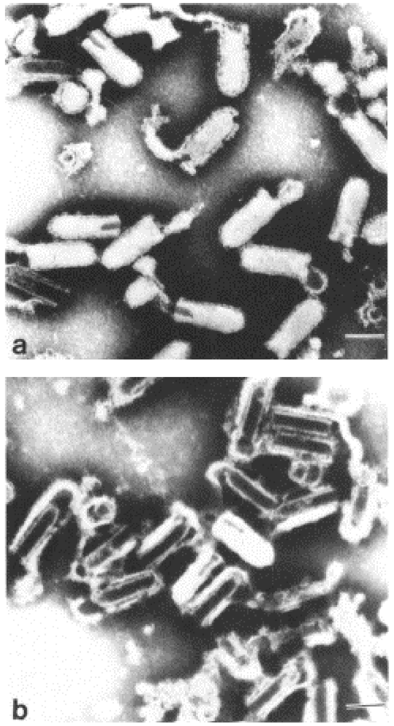
Cochrane et al., 2018

干预
Intervention

持续有效的措施
Approaches with residual activity

- pH调整（酸/碱）pH adjustment (acid/alkalis)
- 精油 Essential oils
- 甲醛类产品 Formaldehyde-based products
- 有机酸 Organic acids
  - 中链、短链、其它 Medium chain, short chain, others

- 各种措施的作用机理不同 Modes of actions differ across mitigant type
  - 破坏病毒包膜：中链脂肪酸
    Disruption of viral envelope – medium chain fatty acids
  - 作用于病毒遗传物质：甲醛
    Interactions with viral genetic material - formaldehyde



Images: Thormar et al., 1987; Vesicular stomatitis virus

干预
Intervention

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DOI: 10.1111/tbed.13749

ORIGINAL ARTICLE

Transboundary and Emerging Diseases WILEY

通过冰块攻毒模型研究不同添加剂降低饲料被污染风险的效果
An evaluation of additives for mitigating the risk of virus-contaminated feed using an ice-block challenge model

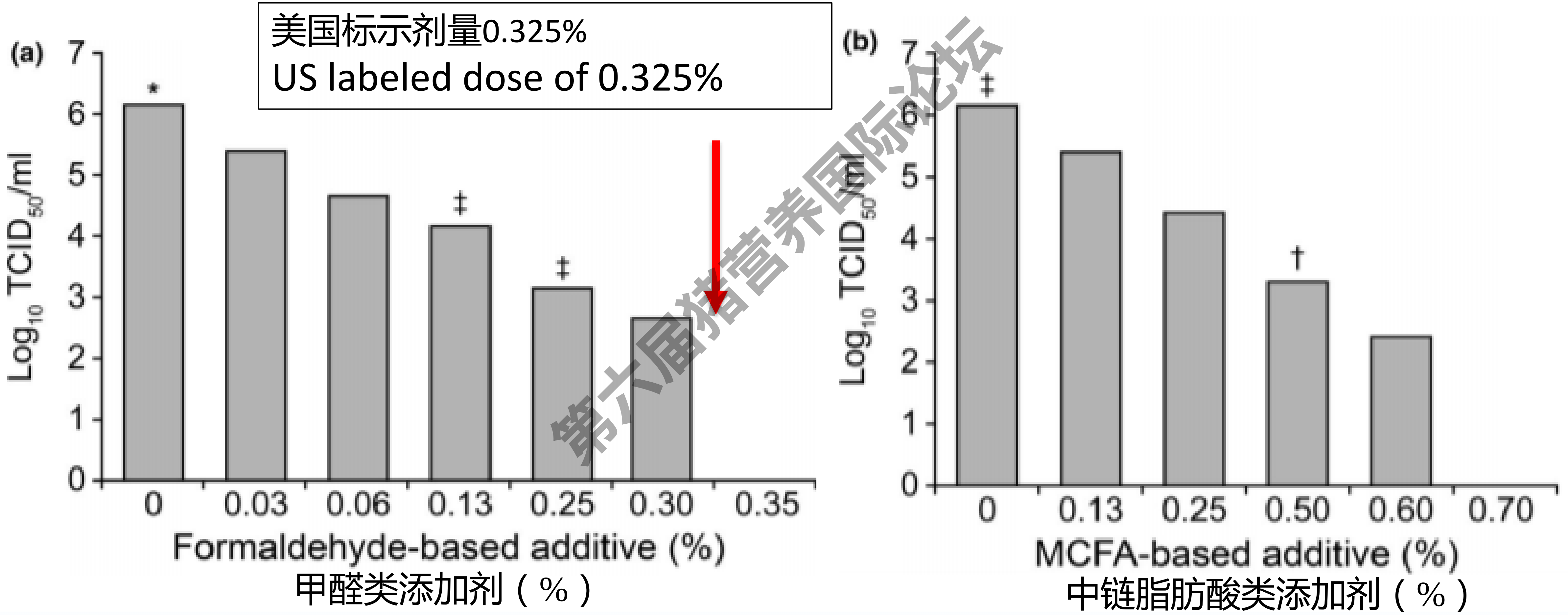
Scott A. Dee[1] | Megan C. Niederwerder[2] | Roy Edler[1] | Dan Hanson[1] | Aaron Singrey[3] | Roger Cochrane[1] | Gordon Spronk[1] | Eric Nelson[3]

- 冷冻的病毒冰块直接放入饲料罐中
  Block of frozen virus applied directly into feed bins
  - A型塞内卡病毒 100 mL SVA Senecavirus A (10^5 TCID50/mL)
  - 蓝耳病病毒 100 mL Porcine reproductive and respiratory syndrome virus (10^5 TCID50/mL)
  - 猪流行性腹泻病毒 100 mL Porcine epidemic diarrhea virus (10^5 TCID50/mL)
- 测试19种不同组合，包括多种饲料添加剂和不同剂量
  19 different combinations of feed additives and concentrations tested

Dee et al., 2021

干预
Intervention

ASFV BA71V体外灭活效果
In vitro inactivation of ASFV BA71V



Niederwerder et al., 2021

干预
Intervention

病毒分离及生物测定
Virus isolation and bioassay

饲料原料Feed ingredient	No treatment	甲醛 Formaldehyde, 6.5 lb/ton		中链脂肪酸混合物 MCFA blend, 20 lb/ton	
		d 0	d 28	d 0	d 28
普通豆粕Conventional SBM	$10^{3.0}$	---	---	---	---
有机豆粕Organic SBM	$10^{3.0}$	---	---	---	+
豆饼Soy oilcake	$10^{3.1}$	---	---	---	---
干犬粮Dry dog food	$10^{2.7}$	---	---	---	+
湿猫粮Moist cat food	$10^{3.0}$	---	---	---	---
湿犬粮Moist dog food	$10^{2.8}$	---	---	---	---
胆碱Choline	$10^{3.2}$	---	---	---	---
猪肉肠衣Pork sausage casings	$10^{2.9}$	---	---	---	---
全价饲料Complete feed	$10^{2.7}$	---	---	---	---
全价饲料（负对照）Complete feed (negative control)	---	ND	ND	ND	ND

--- 阴性bioassay negative; + 阳性bioassay positive

Niederwerder et al., 2021

干预
Intervention

中链脂肪酸和月桂酸单酯对ASFV的灭活效果

In vitro inactivation of ASFV using medium chain fatty acids and glycerol monolaurate

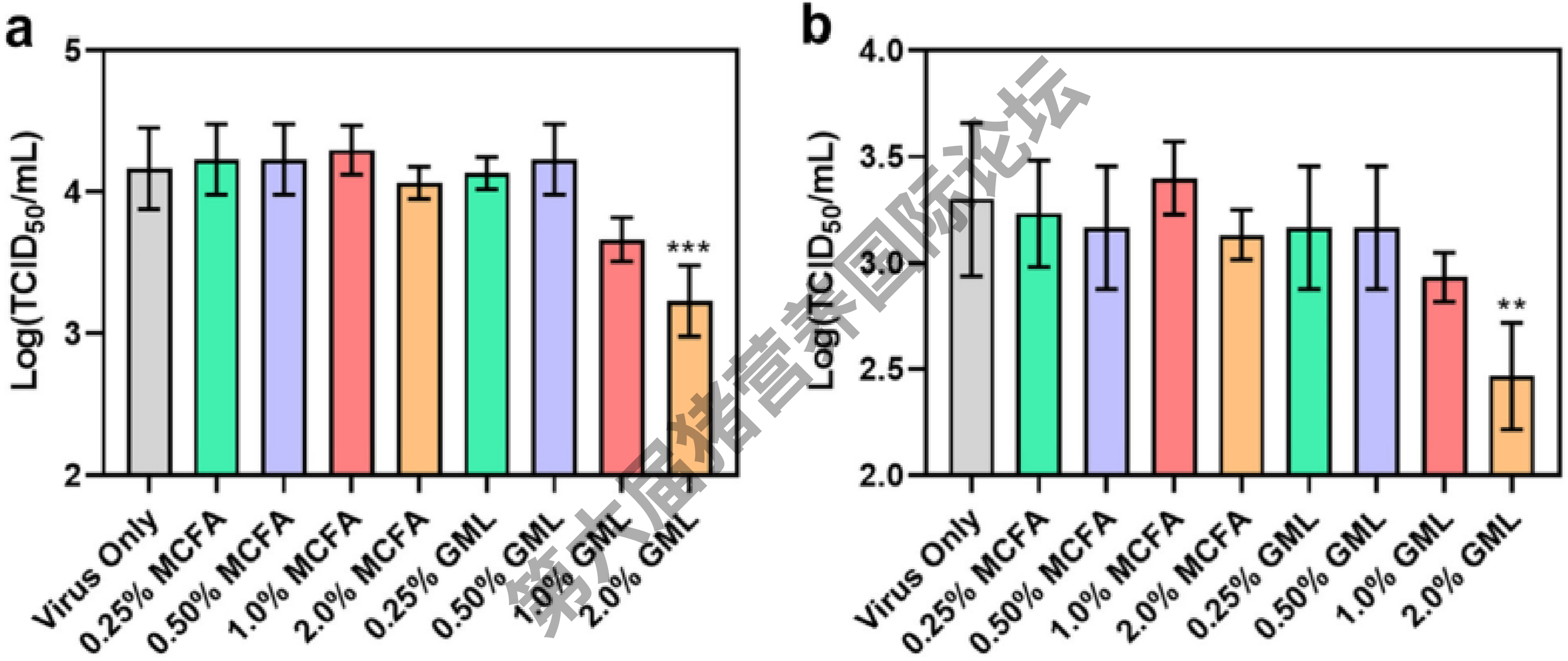


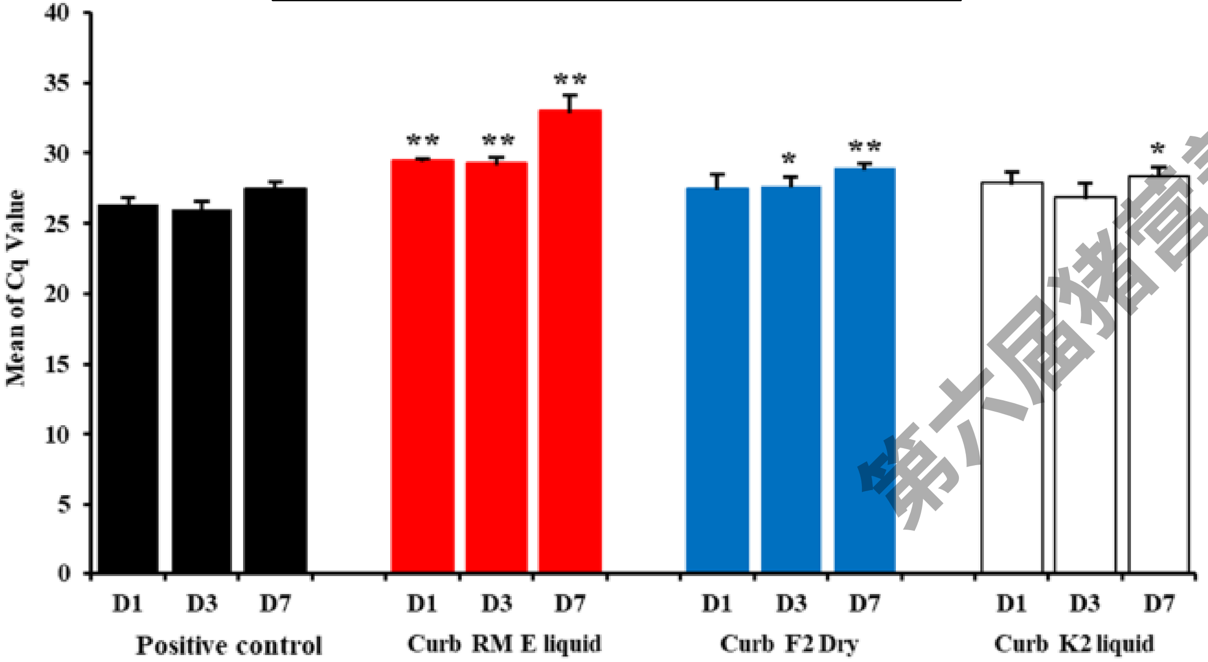
Fig. 2 Effect of MCFA mixture and GML additives on ASFv infectivity in feed. 0–2.0% (wt/wt) feed additives were included in the feed and the effects on ASFv infectivity were measured (**a**) 30 min and (**b**) 24 h post-incubation. Viral titers were measured by CPE-based assay. Data are reported as mean ± standard deviation from three independent experiments (*n* = 3 per group). The markers ** and *** indicate $P < 0.01$ and $P < 0.001$, respectively, versus the virus-only control

干预
Intervention

饲料添加剂产品对ASFV的灭活效果

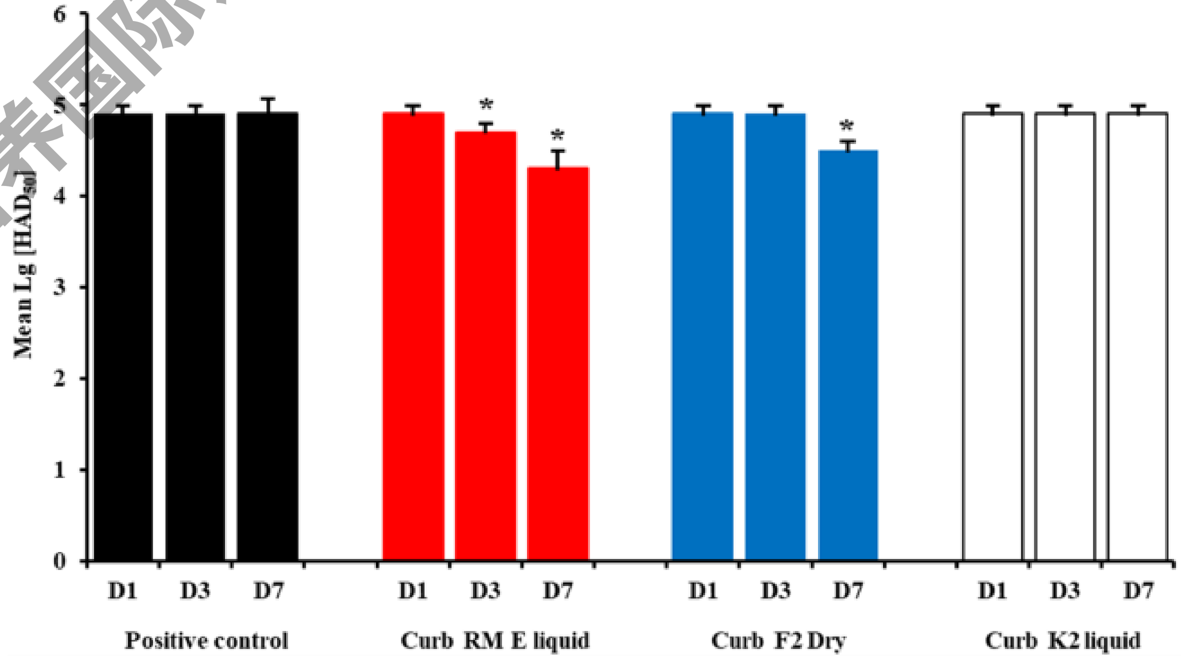
In vitro inactivation of ASFV using commercial feed additive products

遗传物质
Genetic material



正对照 Curb RM E液体 Curb F2干粉 Curb K2液体

病毒传染性
Viral infectivity

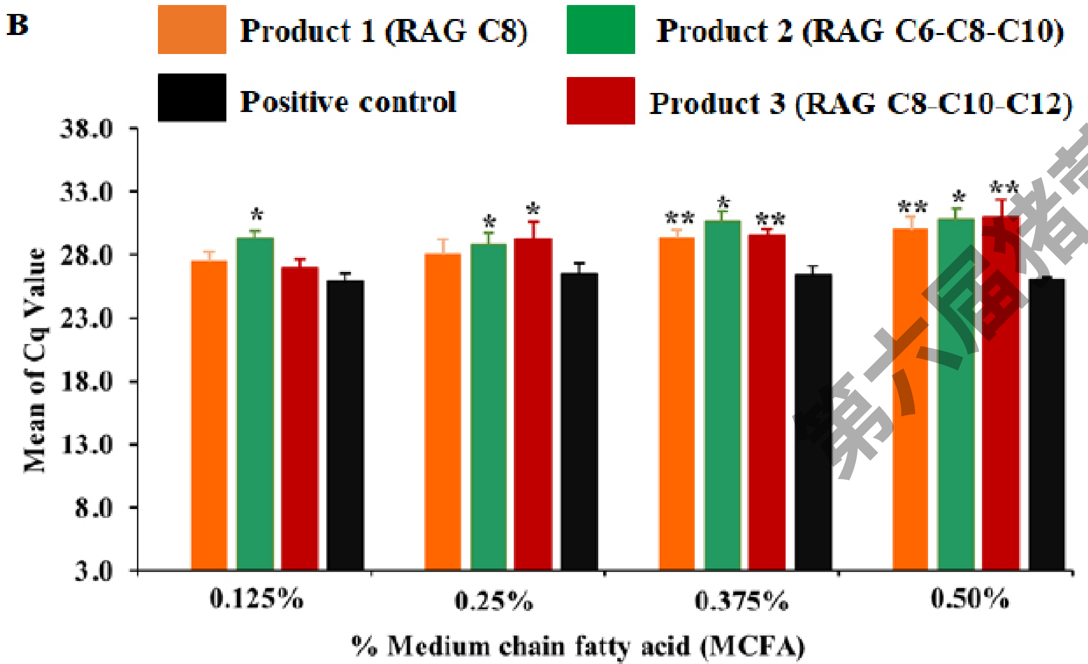


正对照 Curb RM E液体 Curb F2干粉 Curb K2液体

Tran et al., 2020

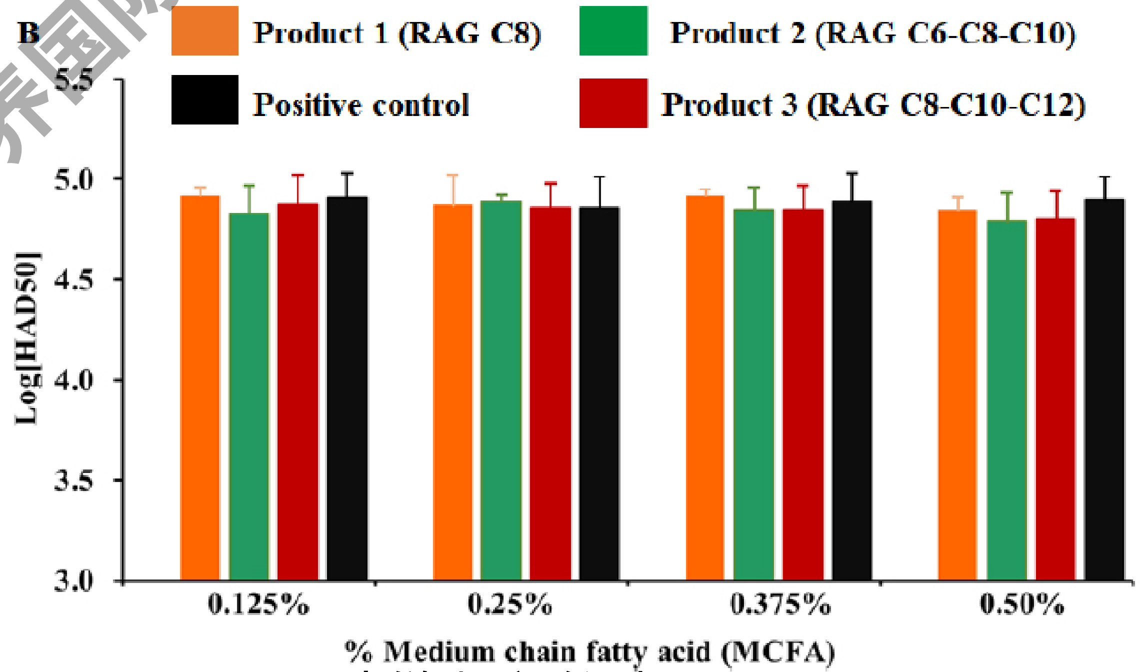
中链脂肪酸对ASFV的灭活效果
In vitro inactivation of ASFV using medium chain fatty acids

遗传物质
Genetic material



中链脂肪酸添加量（%）

病毒传染性
Viral infectivity



中链脂肪酸添加量（%）

Tran et al., 2021

干预
Intervention

堪萨斯州立大学饲料添加剂效果汇总
KSU Feed Additive Summary

访问Available at:
www.ksufeed.org

K·STATE Research and Extension

可用信息汇总
Summary of available information:

Updated April 2022
To check for updates, visit www.ksufeed.org

公司 Company	产品名 Product name	活性成分 Active ingredient(s)	添加量 Inclusion, lb/ton	价格 Pricing[1]	有效试验数量 # of published studies documenting efficacy[2]	试验总数 Total # of published studies
ADM	DaaFit & DaaFit S	Lauric and myristic acids and glycerol monolaurate	10 (Daafit S) 6 (Daafit)	$$	1	1
ADM	DaaFit PLUS	Lauric Acid, GML-90, formic acid, short chain fatty acids	10	---	1	1
Alltech	Guardian	Lactic acid, propionic acid, essential oils	8 (dry) 5.3 (liquid)	$$$ (dry) $$ (liquid)	3	3
Anitox	Termin8	Formaldehyde, propionic acid (liquid or powder form)	6	---	0	0
Anpario	pHorce	Formic acid, propionic acid, ammonium formate	6	$$	1	1
DSM Nutritional Products	VVC Premix	Blend of essential oil compounds and benzoic acid	7	$	2	3
Feed Energy	R2	Short, medium, long chain fatty acids and essential oils	60 (R2 active ingredients along with added fats/oils)	$ (active ingredient)	1	1
Feedworks USA	LipoVital GL-90	Glycerol monolaurate	2 to 4	$$	0	0
Form A Feed	Prohibio-R	Medium chain fatty acid and monoglyceride, organic acids	4-5	$$$	0	0
Furst McNess	Furst Protect	Monoglycerides, Essential oil, natural extracts	8	$$$	1	1
Kemin	FeedSURE MG	Monoglyceride blend, organic acids	3.3 to 7.7	$$	1	1
Kemin	Sal CURB	Formaldehyde, propionic acid	6.5	$	8	8
Novus	Activate DA	Organic acids, 2-Hydroxy-4-Methylthio Butanoic acid	10	$$$	2	3
PMI	Vitacy FeedLock	Blend of activated medium chain fatty acids	4	$	0	0
Provimi	Vigilex	Fatty acids	8	$	1	1
Ralco	Dual Defender	Phytonutrients	2	$$ to $$$	1	1

[1] Pricing at recommended inclusion. $ = < $10/treated ton; $$ = $10-15/treated ton; $$$ = > $15/treated ton. --- indicates that pricing estimate not available.
[2] Efficacy defined as a reduction in the infectivity of viral samples (PEDV, PRRSV, SVA, ASFV, FMDV) using either a cell culture based assay or swine bioassay. Other non-peer reviewed data may be available to support the products such as meeting abstracts and proceedings, but not considered in this summary.

解决饲料安全问题
Addressing Feed Safety

1. 是否可能被污染？
Is it likely to get contaminated?

2. 是否会存活？
Can it survive?

3. 是否会传染？
Is it infectious?

防
Prevention

治
Intervention

生物安全方案成功的关键
Keys to a successful biosecurity program

文化 Culture

在组织的各个层面目标保持一致，实行责任制
Consistent expectations and accountability at all levels of organization

培训 Training

培训、培训、再培训
关注“为什么”
Training and re-training
Focus on WHY

生物安全
Biosecurity

硬件Infrastructure

减少不方便=更一致的行动
Minimize inconvenience = more consistent implementation

持续改进Continuous improvement

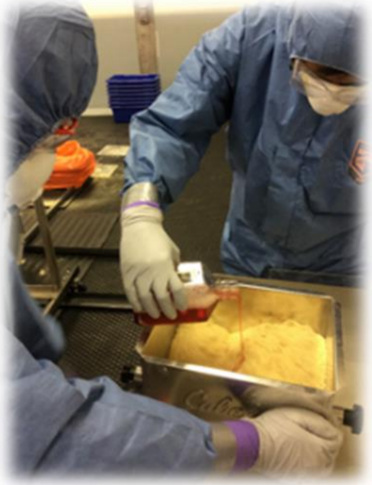
明确不足之处，采取改进措施
Identifying gaps, implement corrective measures

防止疾病从饲料厂传染至猪场
Prevention of disease transmission from feed mill to pig farms

1. 严格的生物安全措施已被证明可以有效控制ASFV和其它病原微生物
   Extreme biosecurity measures have been shown to be effective controlling ASFV and other pathogens
   - 原料生物安全 Ingredient biosecurity
   - 清洗卡车内外 Truck washing (inside and outside)
   - 限制人员活动 Control people movement
   - 即时控制或持续控制措施 Point-in-time or residual control strategies

2. 取样并监督，以明确生物安全防范中的不足之处
   Sampling and surveillance to identify gaps in biosecurity practices.

堪萨斯州立大学饲料安全团队
Kansas State University Feed Safety Team



Dr. Jordan Gebhardt –诊断医学/病理学 Diagnostic Medicine/Pathobiology
Dr. Cassie Jones – 动物科学与工业 Animal Sciences & Industry
Dr. Chad Paulk –饲料科学 Feed Science
Dr. Jason Woodworth – 动物科学与工业 Animal Sciences & Industry

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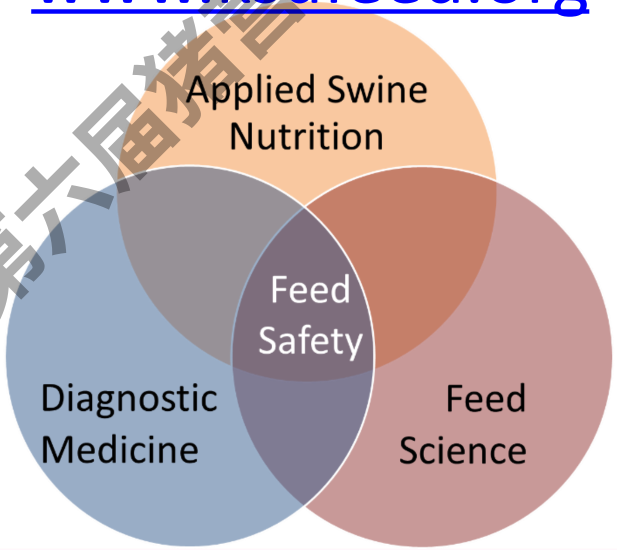
Kansas State University applied swine nutrition

Diagnostic Medicine/Pathobiology Kansas State University



Kansas State University Animal Sciences and Industry

Kansas State University GRAIN SCIENCE & INDUSTRY

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THE END

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