Air Quality & Emission Mitigation Strategies for Cage-Free Housing

Hongwei Xin & Lilong Chai

Egg Industry Center; Iowa State University

hxin@iastate.edu

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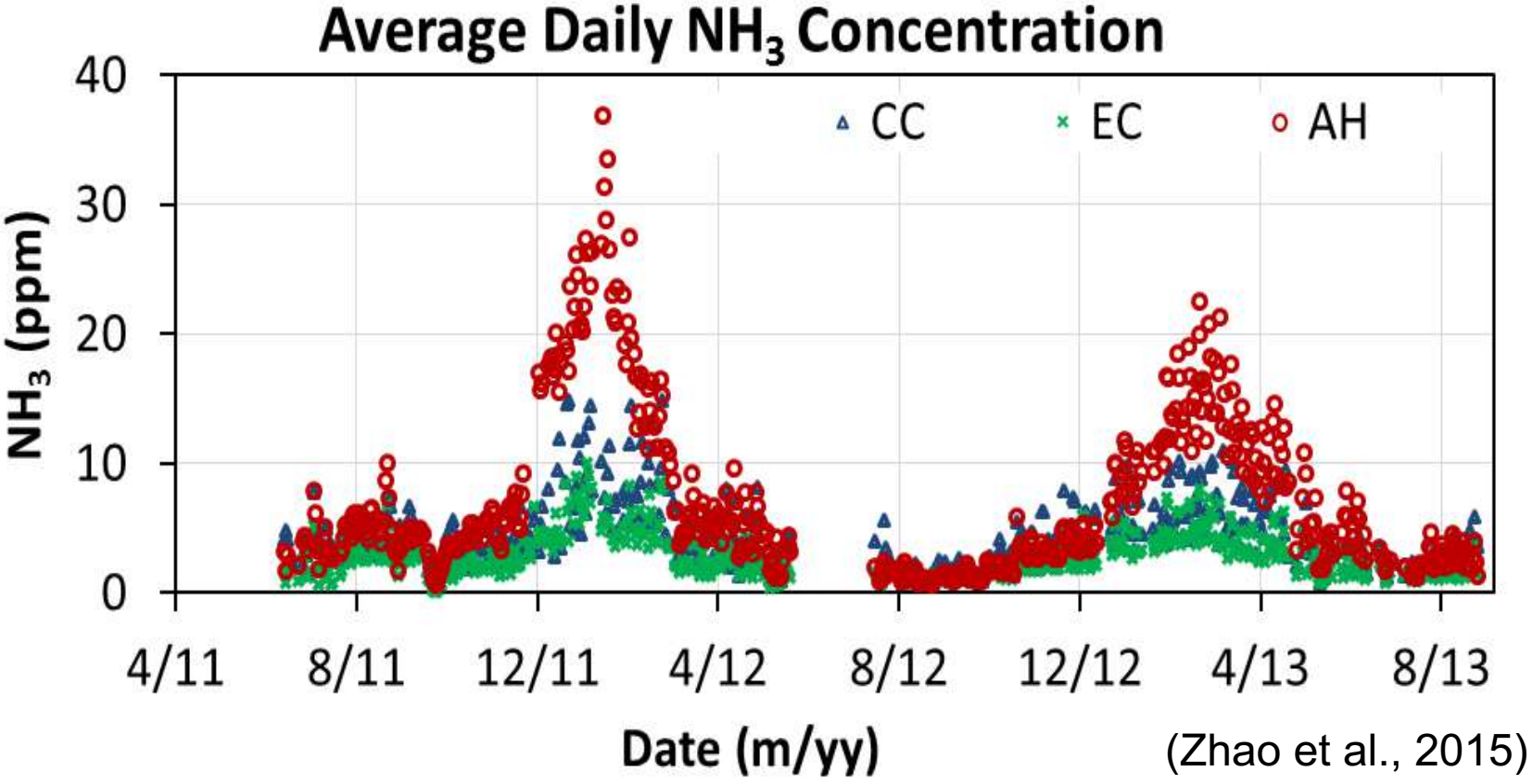
Outline

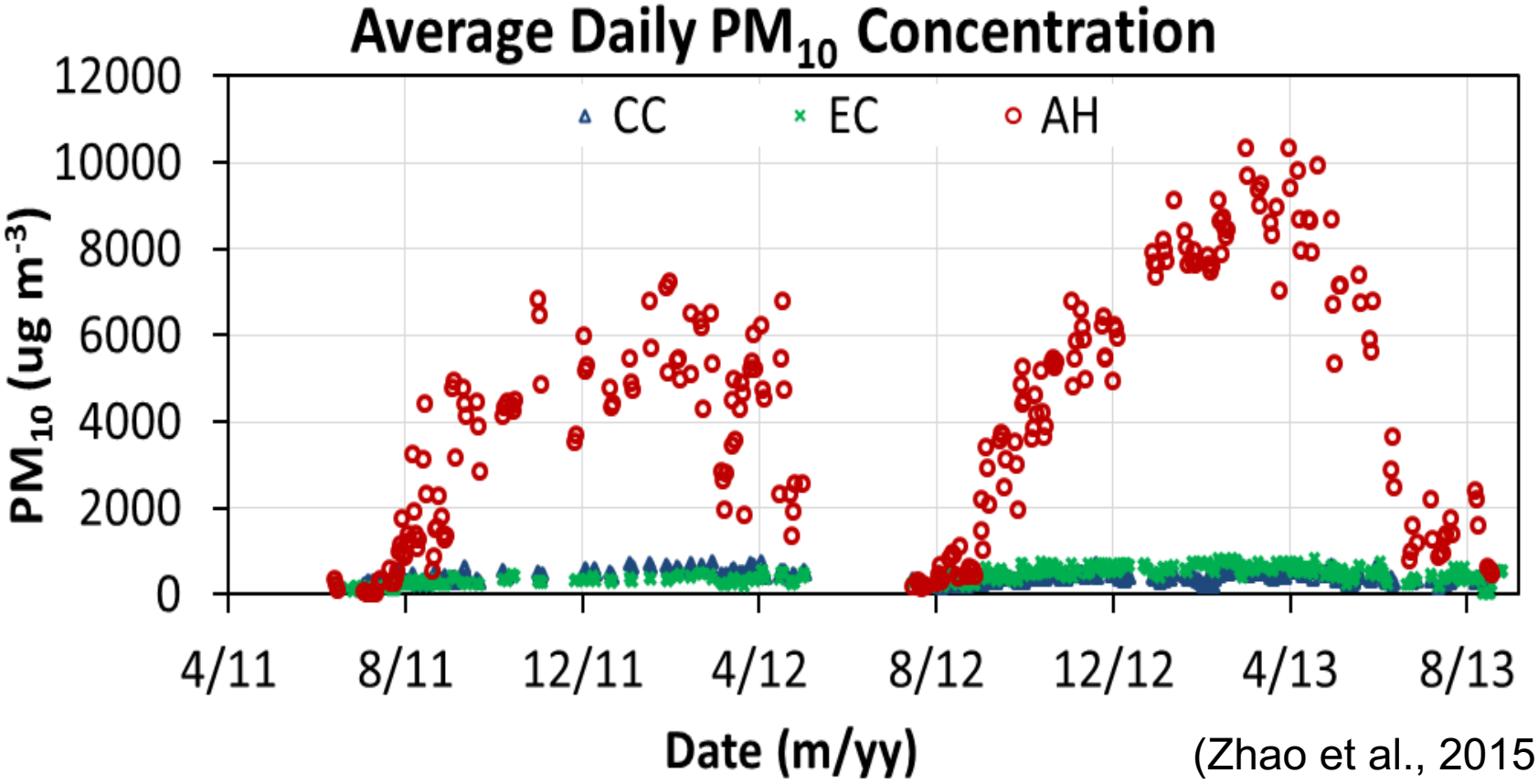
1. Air quality challenges with CF housing
2. Potential mitigation means
3. Future research needs

Ammonia Levels of Conventional Cage, Enriched Colony and Aviary Houses



(Zhao et al., 2015)

PM_{10} Levels of Conventional Cage, Enriched Colony and Aviary Houses



(Zhao et al., 2015)

Mitigation Strategies

1. Indoor air quality – *potential impact on birds and workers*
2. Emissions to atmosphere – *potential impact on environment and ecosystems*

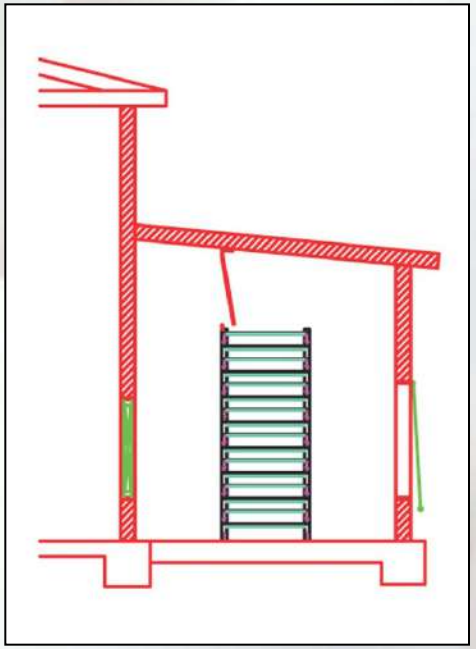
Mitigation Strategies

- ✓ Dietary manipulation to reduce ammonia
  - 1% lower dietary crude protein reduced NH_3 emission by ~10% in HR layer houses (Liang et al., 2005)
  - Dietary fibers (wheat middling, soy hull) reduced NH_3 emissions (41-46%) from layer manure (Roberts et al., 2007)
  - DDGS (10%) and EcoCal (7%) reduced NH_3 emission by 14% and 39%, respectively, in HR layer houses (Li et al., 2012)

Mitigation Strategies

- ✓ Manure drying on belts to reduce NH_3 generation

In-house air duct drying



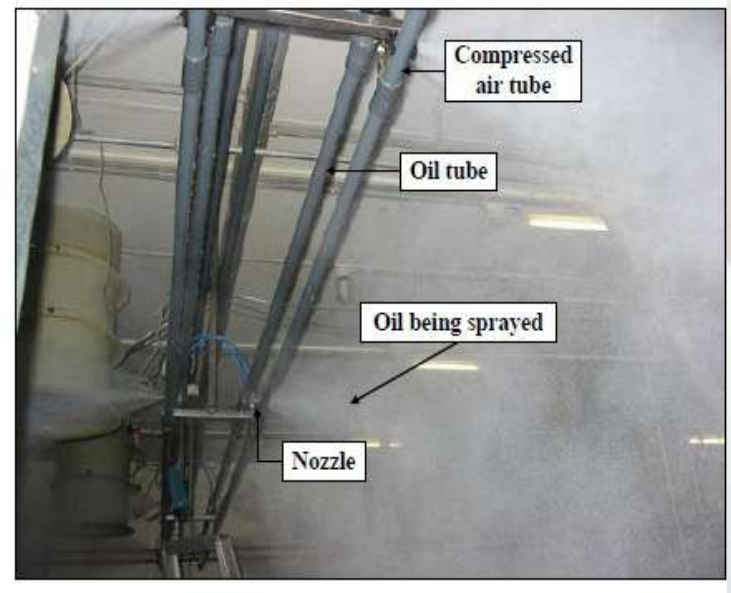
Drying with exhaust air heat

Mitigation Strategies

- ✓ Control the amount and moisture content of litter/manure on the floor
  - Wet litter gives off more ammonia
  - Wet litter also tends to cake more
  - Dry litter leads to more dust
  - Proper ventilation rate and air distribution throughout the house are key
  - Use of scraper to control litter depth

Mitigation Strategies

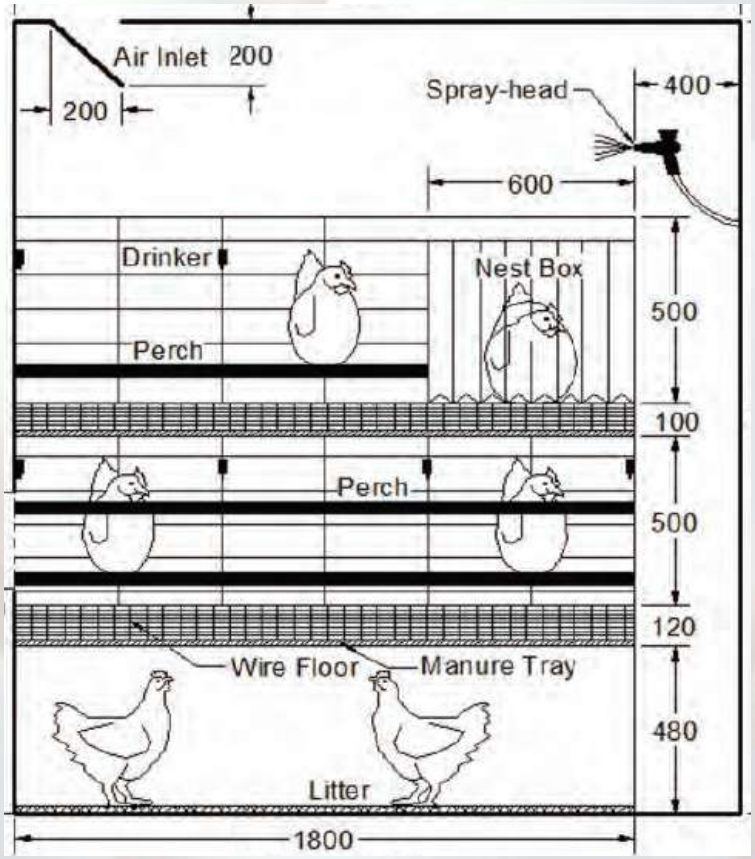
- ✓ Oil spray to suppress dust generation
  - 53-60% reduction for broiler house
  - 21-31% for CF layer house (low coverage)



(Winkel, 2016)

Mitigation Strategies

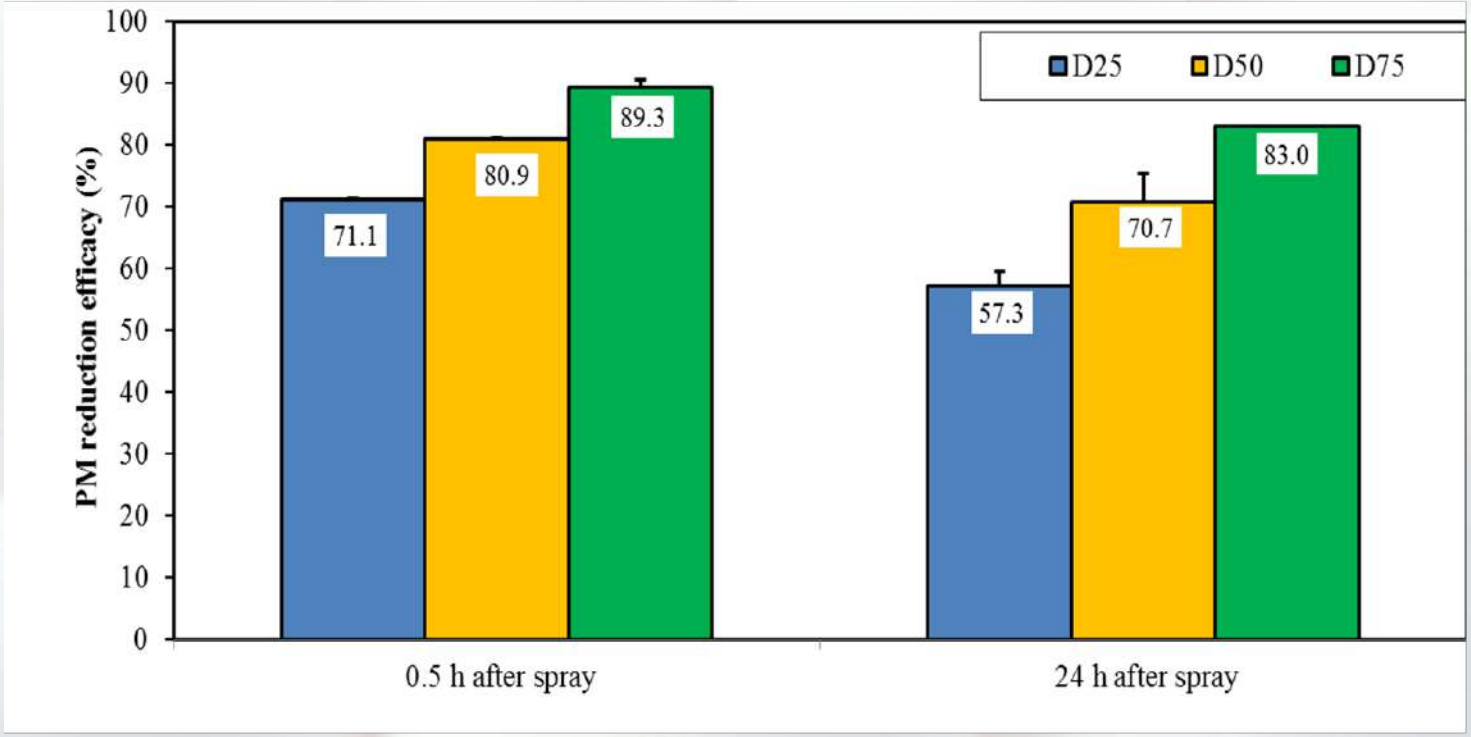
- ✓ Electrolyzed water (EW) spray to suppress dust generation
  - 49% reduction in PM and airborne bacteria (80 mg free chlorine/L; 80 mL/m^2 spray for 15 min per day).



(Zheng et al., 2014)

Mitigation Strategies

- ✓ Higher dosages of EW lead to greater PM reduction efficiencies

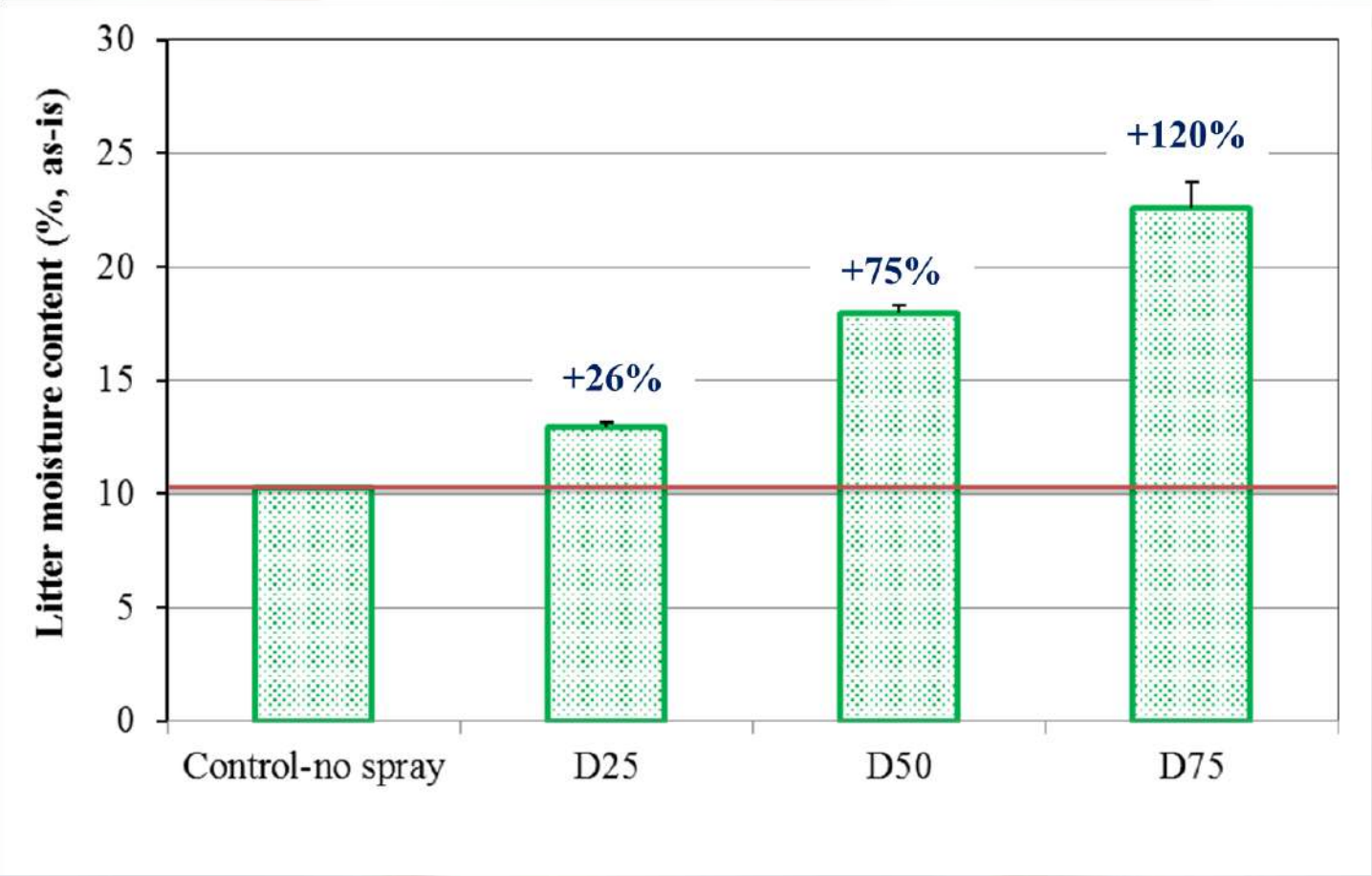


D25, D50, and D75= 25, 50, and 75 mL [kg dry litter]$^{-1}$ d^{-1}

(Chai et al., 2016)

Mitigation Strategies

- ✓ Litter moisture content increase with EW dose

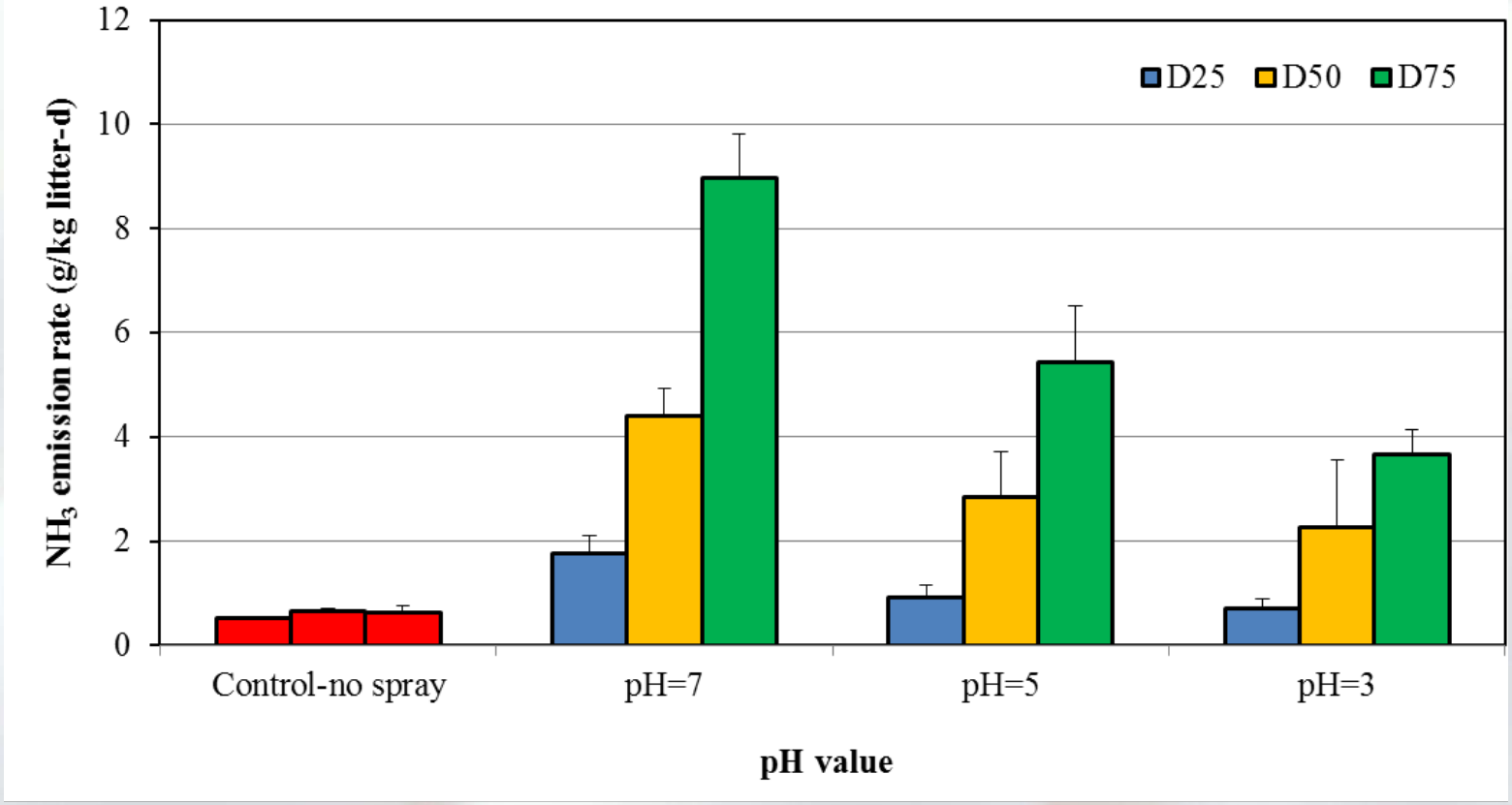


D25, D50, and D75 = 25, 50, and 75 mL [kg dry litter]$^{-1}$ d^{-1}

(Chai et al., 2016)

Mitigation Strategies

- ✓ Higher EW dose increases NH_3 generation
- ✓ Lower pH-EW decreases NH_3 generation

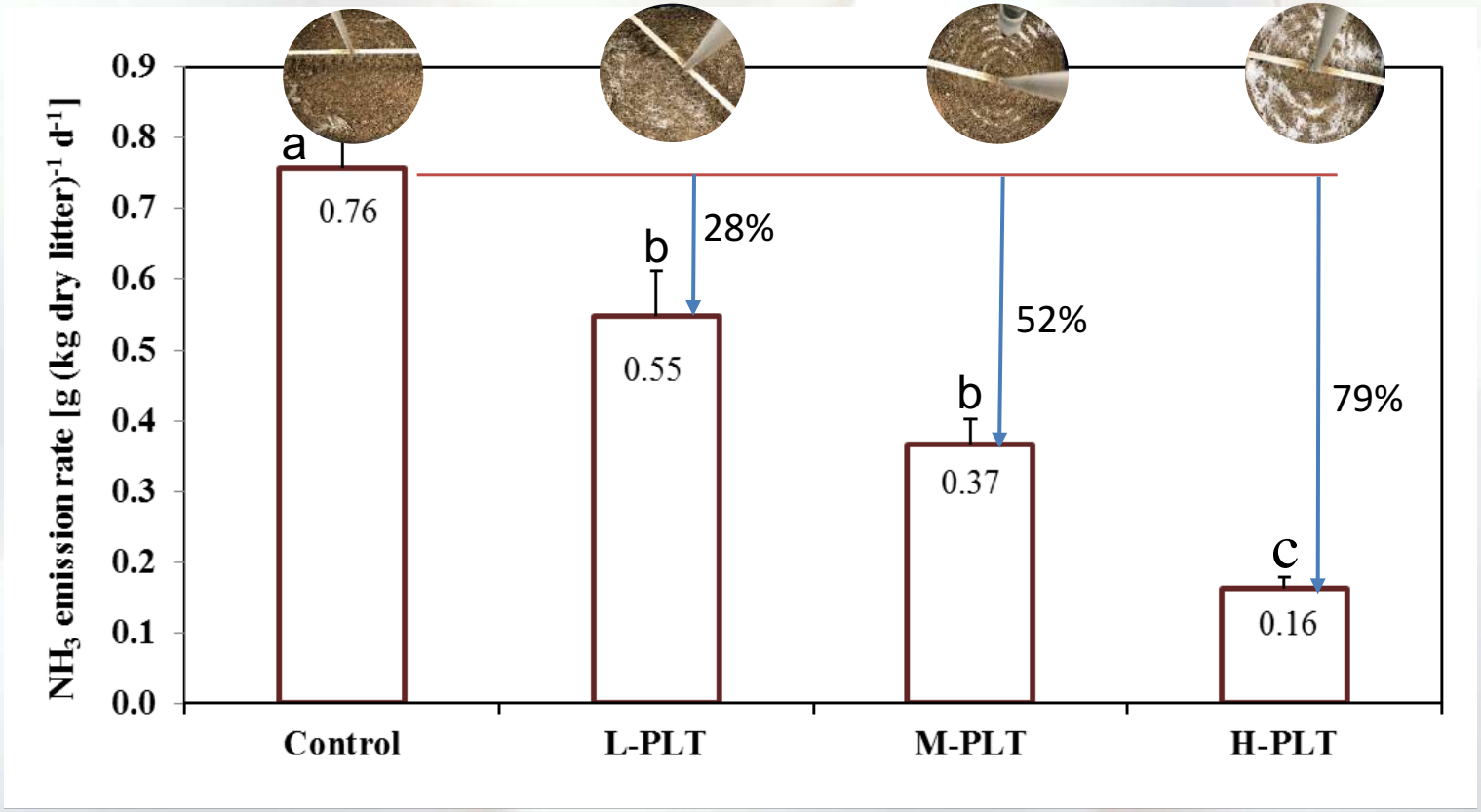


D25, D50, and D75= 25, 50, and 75 mL [kg dry litter]$^{-1}$ d^{-1}

(Chai et al., 2016)

Mitigation Strategies

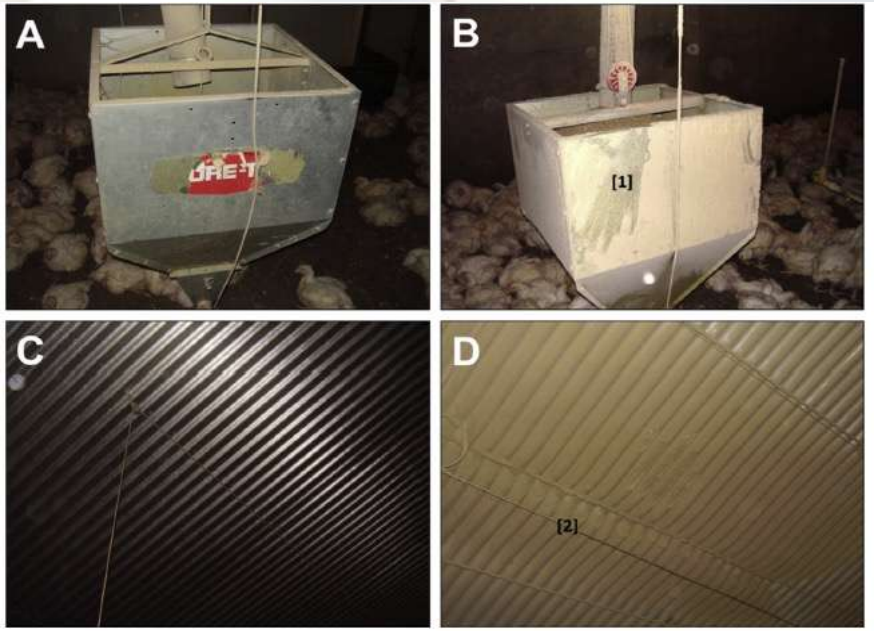
- ✓ Use of litter additive & EW spray (D25) to reduce both PM and NH_3 generation



lb/1000 ft^2: L = 61, M = 122, H = 182 (1.5-inch litter depth) (Chai, 2017)

Mitigation Strategies

- ✓ Electrostatic Precipitation (ESP)



Electrostatic space charge system (ESCS): 43% PM reduction in broiler house (Mitchell et al., 2003)

Electrostatic air ionizer (EAI): Up to 49% PM reduction in layer house (Winkel, 2016).

Challenges: Dust accumulation on interior surfaces and high voltage.

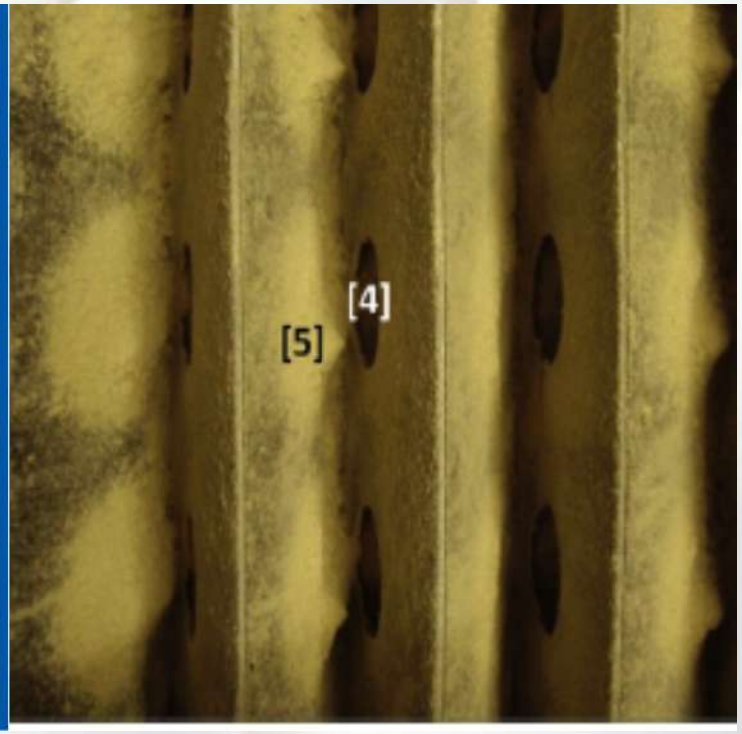
Mitigation Strategies

- ✓ Electrostatic Air Ionizer (EAI)

Electrostatic precipitator system (EPI): 45-57% PM emission reduction from exhaust air of layer house (Winkel et al., 2012)

Mitigation Strategies

- ✓ Dry filter (commercially available)



PM10 removal efficiency: 36%-55% (mean of 40%) for commercial CF house, but PM2.5 removal efficiency was low (<10%) (Winkel et al., 2015)

Mitigation Strategies

- ✓ Biocurtain™ (less or plus EPI)

Ammonia emission reduction: 8% (less EPI) or 17% (plus EPI)
PM emission reduction: 39-43%
Relative low cost (e.g., $0.06 per broiler grown) (Jerez et al, 2013)

Mitigation Strategies

✓ Vegetative buffer

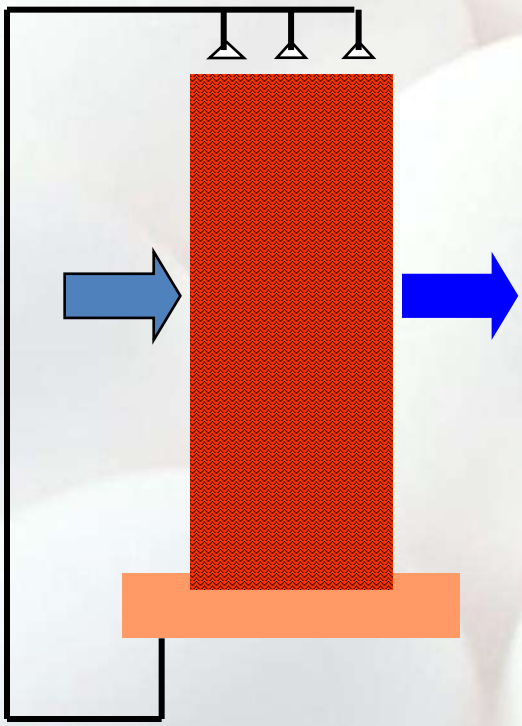
Patterson (2013)

Malone et al. (2006)

- PM reduction: 49±27% (33 d)
- NH_3 reduction: 46±31% (29 d)
- Odor reduction: negligible
- Low cost (e.g., $0.05/pig over 20 yr; Tyndall, 2008)

Mitigation Strategies

- ✓ Wet scrubber (single-stage)



PM removal: 41-46% (43%)

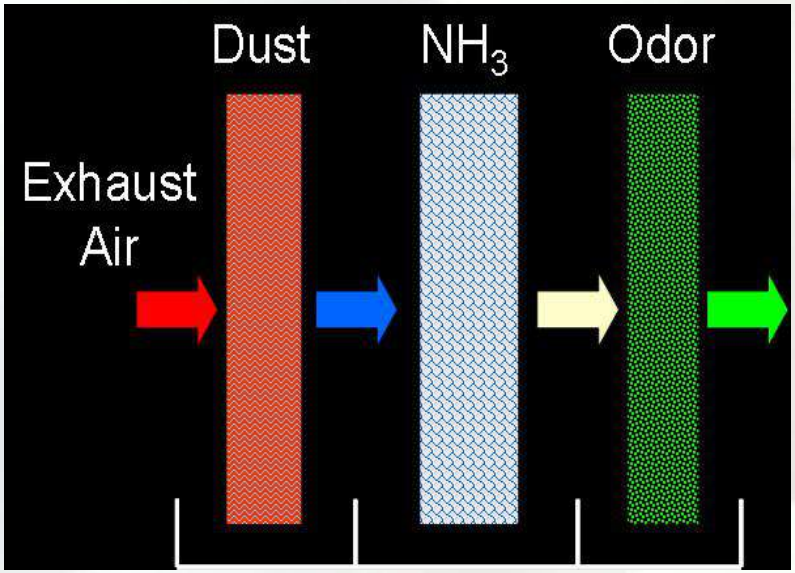
NH_3 removal: 63-98% (81%)

Cost: $42/pig space in capital; $15/yr/pig space in operation

(Melse et al., 2005; 2008)

Mitigation Strategies

- ✓ Wet scrubber (3-stage)



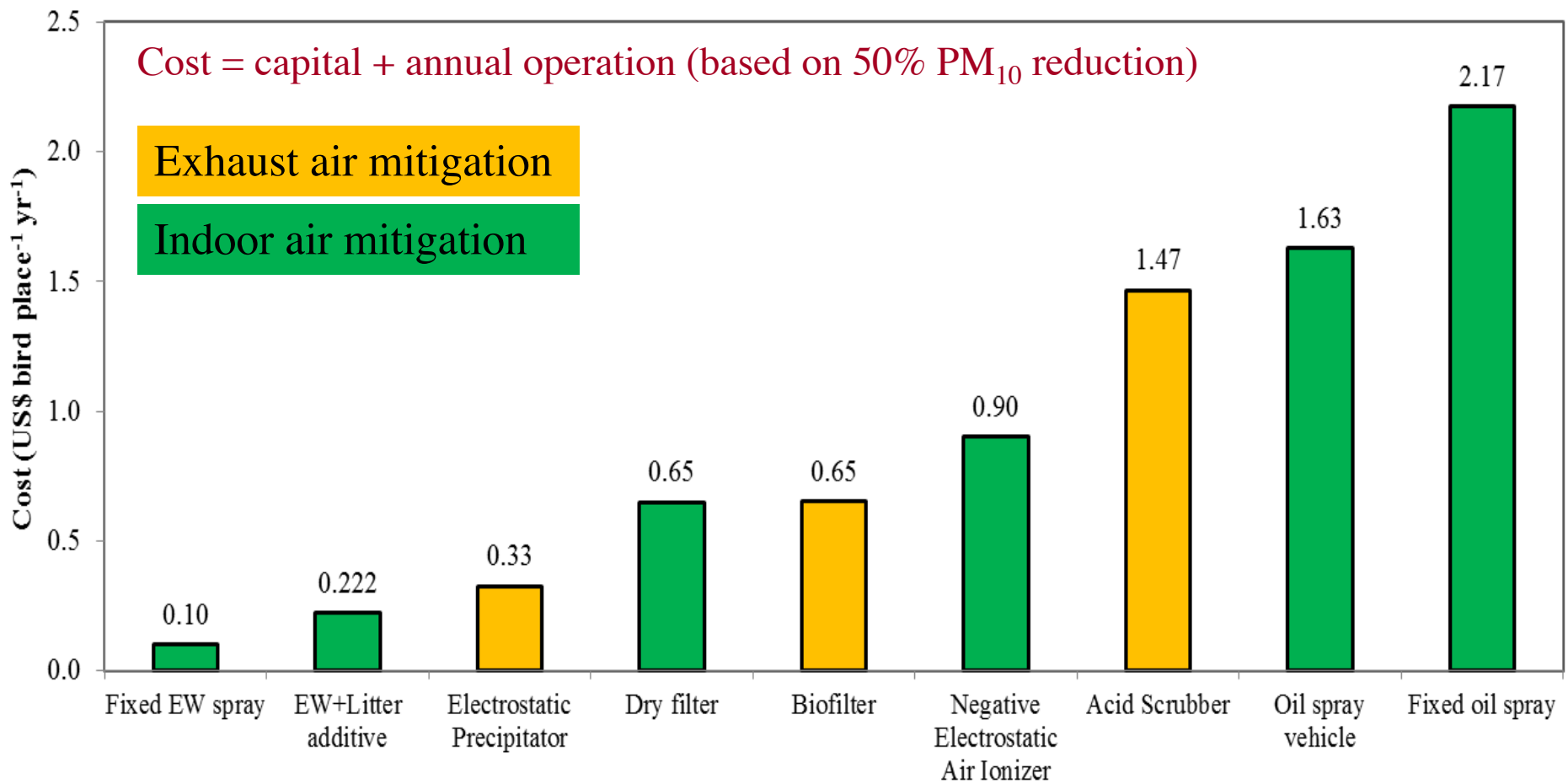
- PM reduction: >70%
- NH_3 reduction: 95%
- Cost: $72/pig space in capital; $19/yr/pig space in operation

(Melse & Ogink, 2005)

Summary of Mitigation Strategies

Strategies	PM reduction	Effect on NH_3	AB reduction	Reference
EAI	43-52%	No effect	>50%	Mitchell et al. 2000; Winkel et al., 2015
Dry filter	40%	No effect	Not reported	Winkel et al., 2015
Oil/oil-water spray	15-65%	No effect /Increased	Not reported	Ellen et al., 2000; Winkel, 2016
Acid scrubber	40-94%	40-95% reduction	Not reported	Hadlocon et al., 2014; Melse, 2009; Ru et al., 2017
Bio-filter	70%	36-89% reduction	Not reported	Tymczyna et al., 2004; KTBL, 2008
EW spray	49-70%	Increased	>50%	Zheng et al., 2014; Chai et al., 2017

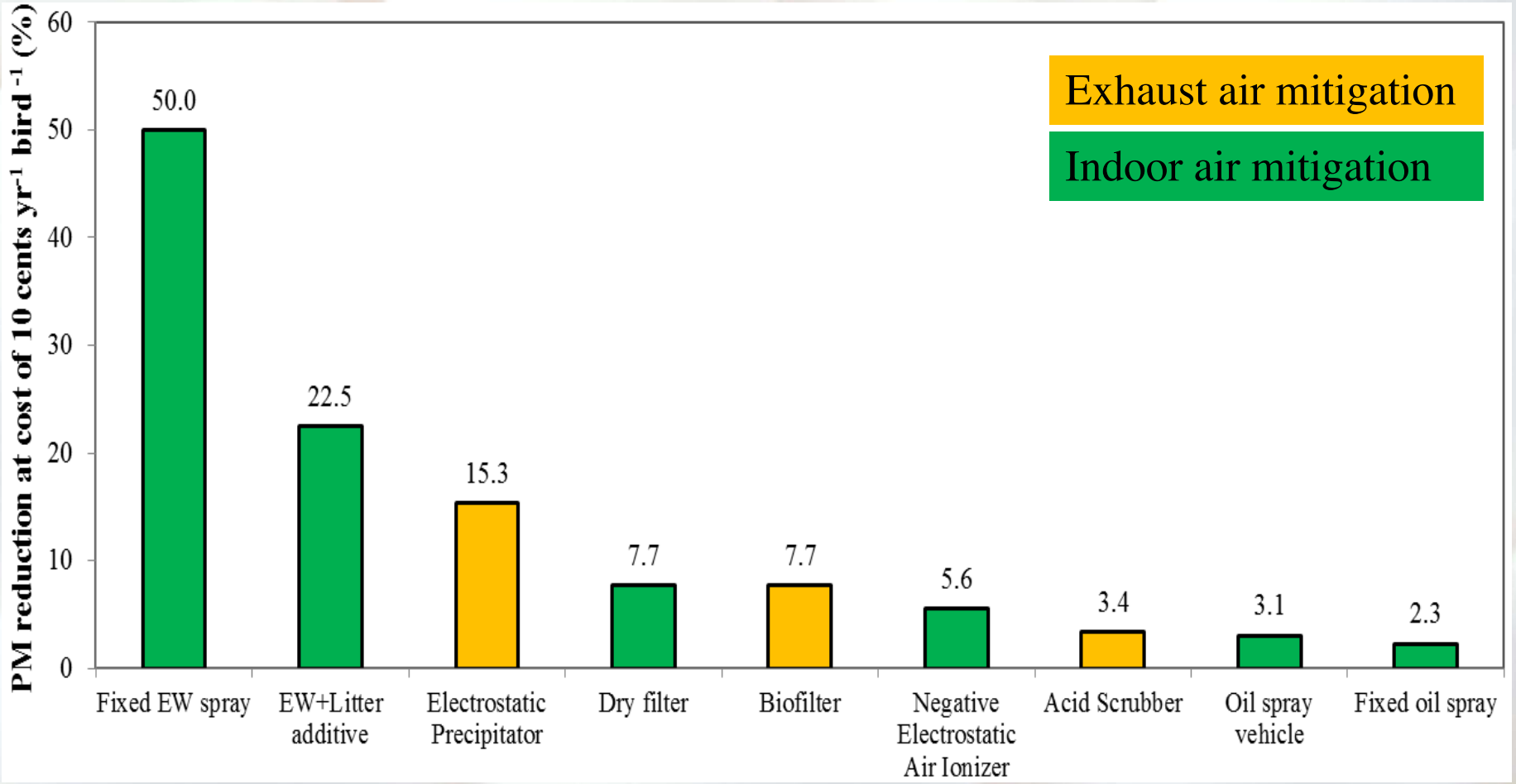
Costs of Mitigation Strategies



(Winkel., 2016; Chai et al., 2017)

PM Reduction at a Fixed Cost

($0.10/bird/yr)



Further Research

- Explore strategies to reduce ammonia and PM generation at the same time
- Verify promising strategies under field conditions
- Reduce the cost of technically effective strategies
- Reduce manure deposition on litter floor through improved system design

Summary

1. Cage-free housing has some unique and inherent air quality challenges.
2. Good manure management and proper ventilation can alleviate the problems.
3. Mitigation means have various levels of effectiveness. Some are cost prohibitive.
4. System design and bird management to reduce manure deposition on floor will be beneficial.