Effect of heat treatment and feed acidification on feed quality and salmonella control

- *Are our feed processing temperatures too high ?*

Leon Hall
BASF Australia Ltd.

AFMA Symposium
30 October 2018

The Salmonella Problem

- Salmonellosis is one of the most common and widely distributed food-borne diseases
- Contaminated feed is the main source of Salmonella infections in animal production
- “Salmonella spp. were detected in a total of 64 (42.66%) chicken meat samples. A very high resistance rate (≥89.28%) to vancomycin, tetracycline, streptomycin, or nalidixic acid was found.” (from: “Prevalence and characterization of salmonella isolated from chicken meat in Turkey.” Siriken et al., 2015)

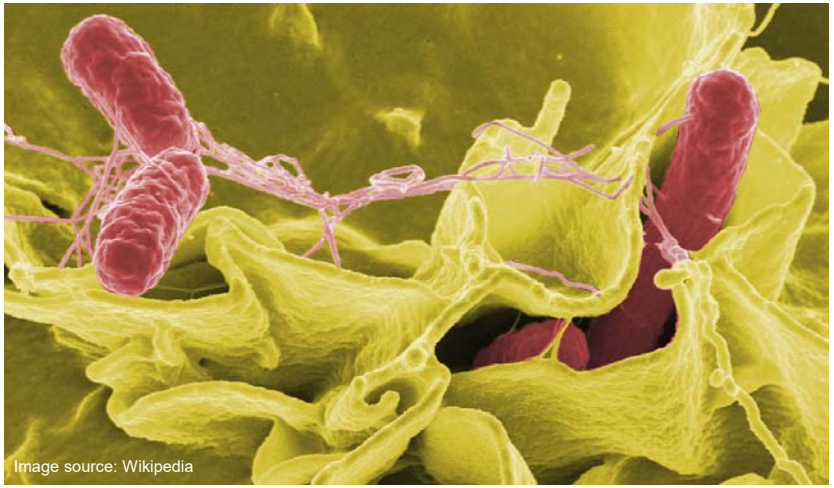
Image source: Wikipedia

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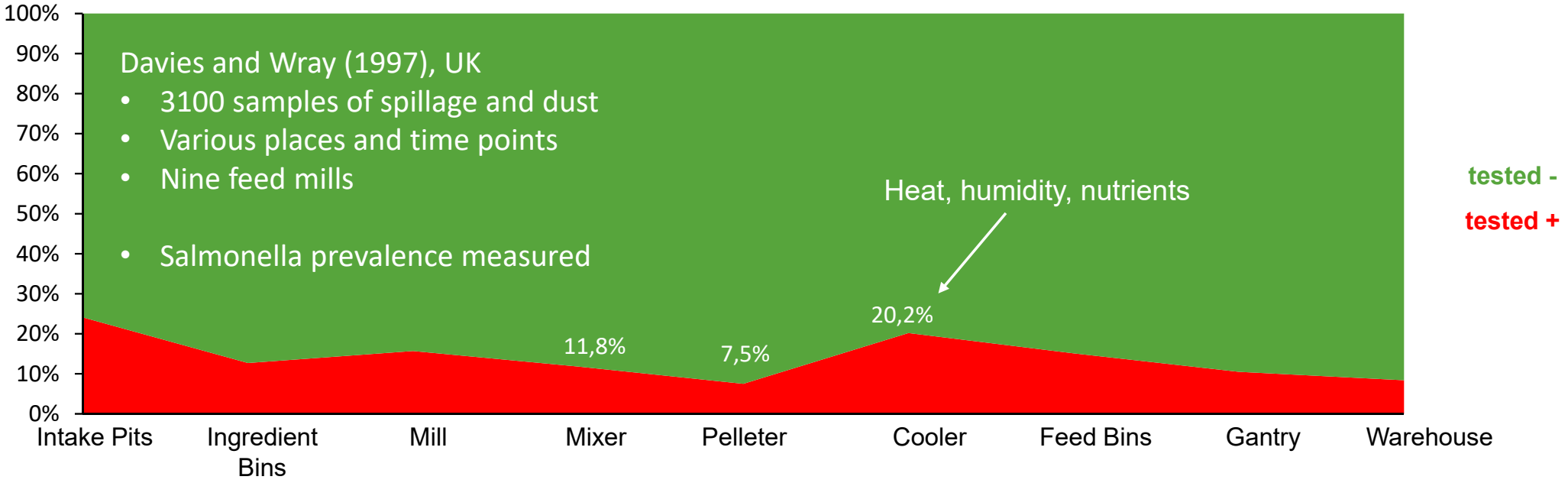
Pelleting as sterilisation method

- Steam conditioning + pelleting of feed has become a standard practice to improve feed hygiene (feed sterilisation)
- Salmonella is heat sensitive but above strategy does not prevent recontamination



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Pelleting has benefits

- Gelatinisation of starch increases pellet durability index (PDI)
- Lower wastage, better ease of handling, improved FCR

- Less time and energy spent consuming feed (Jensen, *et al.*, 1962)

	Avg. times at feeder / 12 hours	Time spent eating / 12 hours (minutes)	Feed consumed / 12 hours / bird (gram)
Mash	35	103	38
Pellets	27	34	37

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Pellet temperature

- A **pelleting temperature** of 88°C without any major fear of vitamin destruction or decreased bird performance is suggested by Leeson (1997)

- In general, "pelleting temperature" at feedmill level mostly refers to "conditioning temperature" as read from feedmill's control panel

- Pelleting temperature (when referring to conditioner temperature) ≠ Pellet temperature
  - A few more °C are added by pelleting press (5-10°C ?)

- **Pellet temperature** = temperature of pellets as they exit the pellet press
  - E.g. hot pellets collected in a coffee flask, sealed and °C measured with a thermometer
  - Could be significantly higher than the "pelleting temperature"

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Reasons for heat treating feed

- Improve feed hygiene
- Increased feedmill throughput when pre-conditioning (Skoch *et al.*, 1981)
  - +150% (65°C) to +175% (78°C) improvement over cold pressed (21°C)
- Improved pellet durability

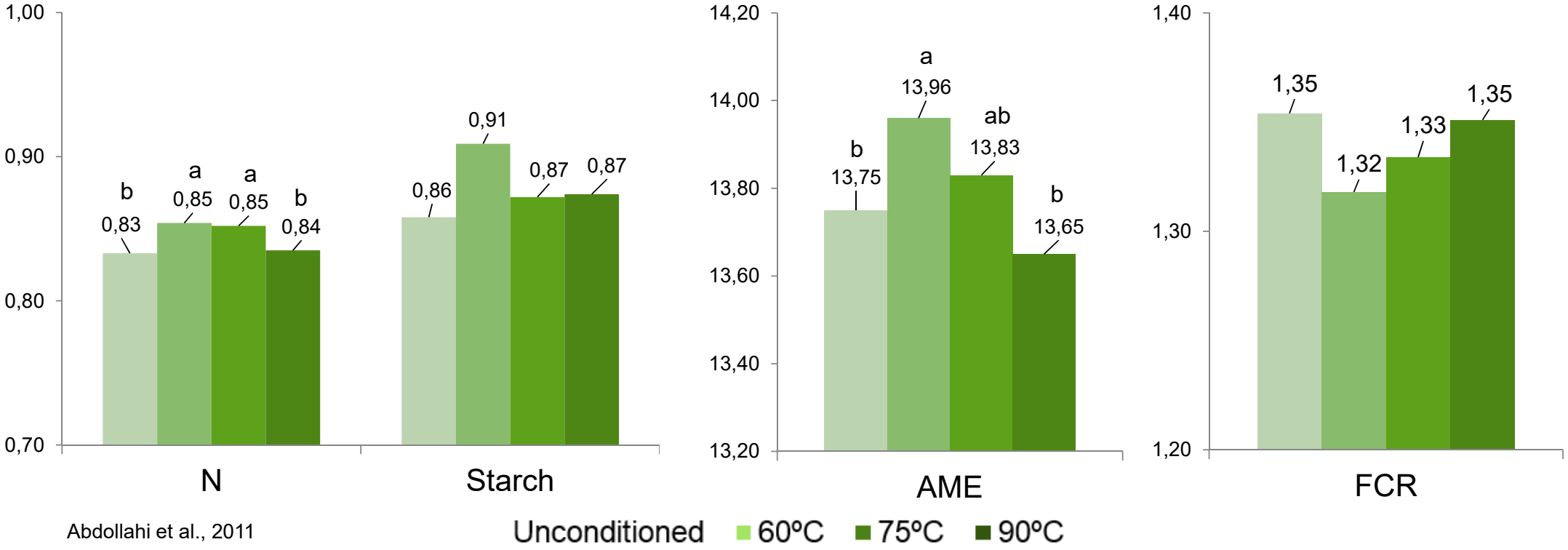
(PDI,%)	60ºC	75ºC	90ºC
Wheat*	77	83	85
Maize**	46	69	85
Sorghum**	31	36	83

(*Abdollahi et al., 2010, British Poultry Sci.)

(**Abdollahi et al., 2010, Anim. Feed Sci. Technol.)

- Improved feed digestibility
  - From the marketing material of a prominent pellet mill manufacturer:
    - "The heat generated during conditioning and pelleting *make the feedstuffs more digestible by breaking down the starches*."

Main effect of conditioning temperature on nutrient utilisation and feed efficiency in wheat-based diets



Abdollahi et al., 2011

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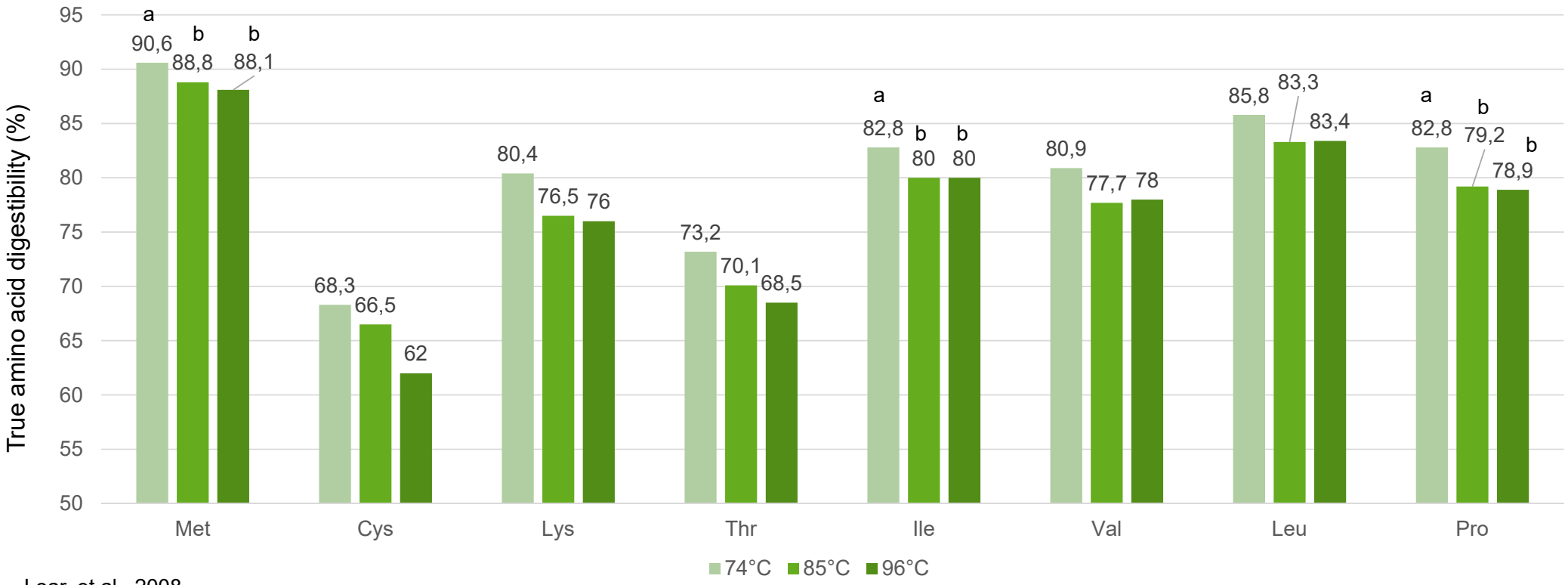
Effect of conditioning temperature on amino acid digestibility



Loar, et al., 2008

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Reasons for heat treating feed

- Improve feed hygiene
- Increased feedmill throughput (Skoch *et al.*, 1981)
  - 250% (68°C) - 275% (78°C) improvement over cold pressed (21°C)
- Improved pellet durability

(PDI,%)	60ºC	75ºC	90ºC
Wheat	77	83	85
Maize	46	69	85
Sorghum	31	36	83

(Abdollahi et al., 2010, Anim. Feed Sci. Technol.)

- **Improved feed digestibility**
  - From the marketing material of a prominent pellet mill manufacturer:
    - "The heat generated during conditioning and pelleting *make the feedstuffs more digestible by breaking down the starches.*"

Research opportunity

- Lowered conditioning temperature raises a concern about feed sterilisation.
- Two-part study launched to investigate:
  - **Kansas State Univ., USA (Microbiology)**
    - Do higher conditioning temperatures actually improve *Salmonella* control?
    - Can acidification with a buffered formic acid (BFA) enable lower pelleting temperatures?
    - Which intervention is better suited to mitigating risks from *Salmonella* contamination?
  - **Massey Univ., NZ (Bird performance, digestibilities and PDI)**
    - if the addition of a BFA could improve the pellet durability index (PDI) - Massey
    - if high heat treatment of feed results in lowered nutrient digestibilities.
    - if lower conditioner temperatures with acidification could be a strategy to maintain feed hygiene and nutrient digestibility.

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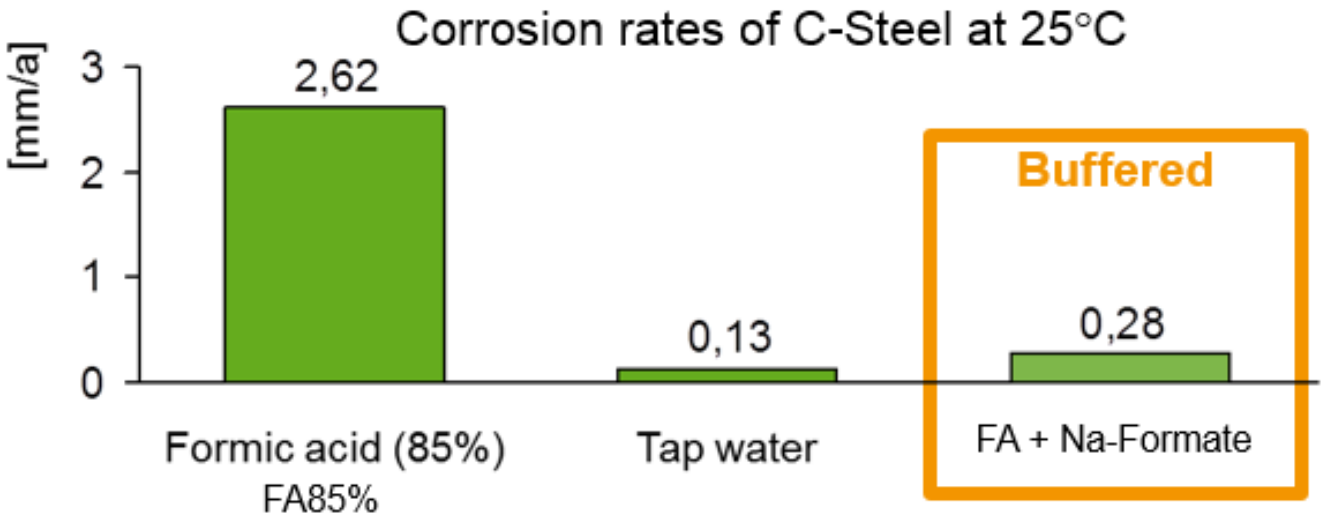
Why a buffered formic acid?



SINTEC, 2007

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STUDY 1

Kansas State Univ., USA

Effect of feed acidification and conditioning temperature on feed hygiene and salmonella recovery from mash and pelleted broiler feed - Jendza, et al., 2018

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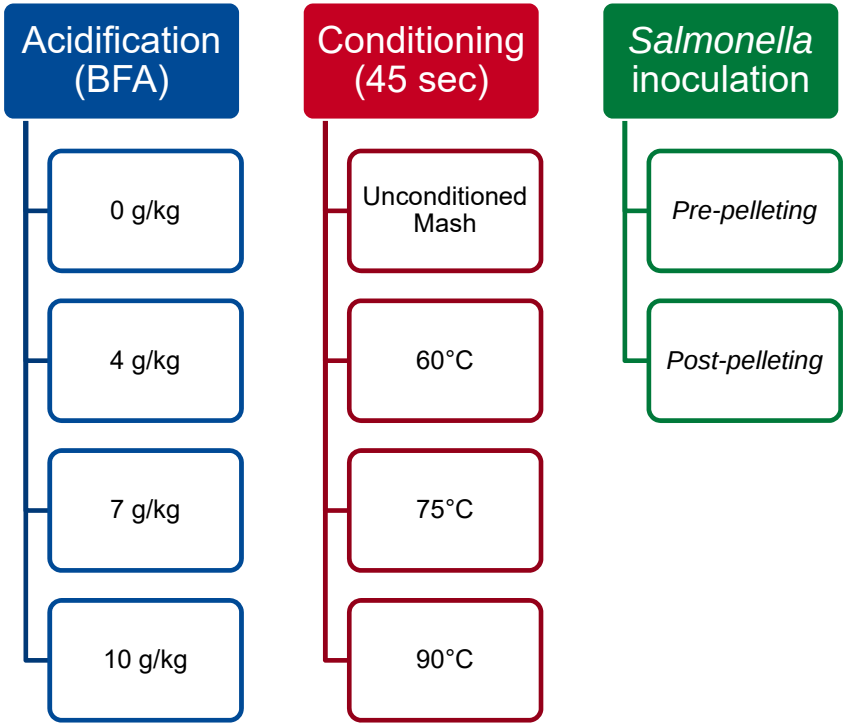
Study 1: Microbiology
Aims and Objectives

- Interaction between **feed acidification, conditioning temperature,** and **timing of inoculation** on feed hygiene in feed inoculated with *Salmonella enterica* subsp. Enteritidis - ATCC 13076 *(SE)*

1. Do higher conditioning temperatures actually improve *Salmonella* control?
2. Can acidification enable lower pelleting temperatures?
3. Which intervention is better suited to mitigating risks from *Salmonella* contamination?



* Buffered formic acid = formic acid + sodium formate

Jendza, et al., 2018

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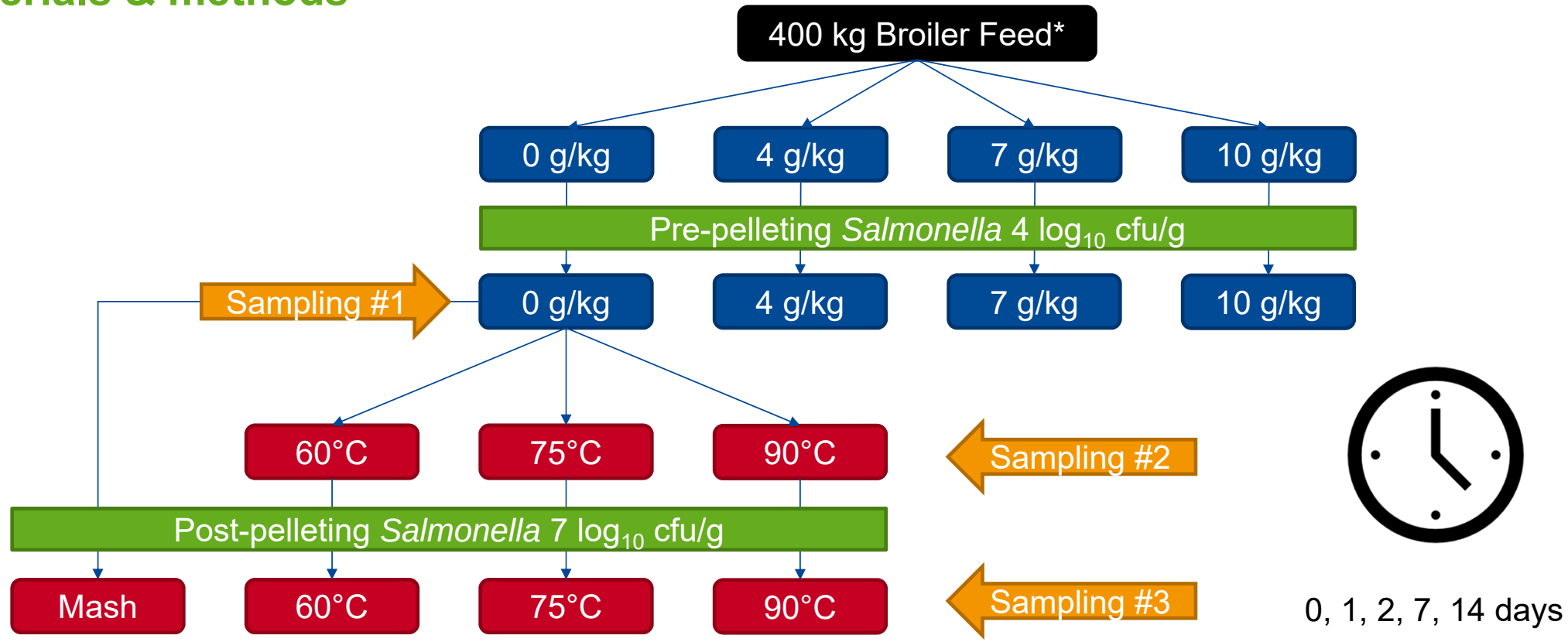
Study 1: Microbiology
Materials & methods



* Three commercial type wheat-soy based broiler diets fed (exact same diets mixed in NZ study)

Jendza, et al., 2018

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Diets used in both studies

	Amasil NA concentration			
Ingredient	0g/kg	4g/kg	7g/kg	10g/kg
Soybean meal	297.70	298.41	298.94	299.47
Wheat	637.19	632.28	628.59	624.91
L-Lysine HCl	3.46	3.45	3.45	3.44
DL-Methionine	2.87	2.88	2.89	2.90
L-Threonine	1.13	1.13	1.13	1.14
Choline chloride	0.25	0.26	0.26	0.27
Vitamin-mineral premix[1]	3.00	3.00	3.00	3.00
Limestone	11.93	11.92	11.91	11.89
Salt	1.42	1.42	1.43	1.43
DCP	9.84	9.87	9.89	9.91
$NaHCO_3$	2.86	1.88	1.15	0.42
Buffered formic acid	0.00	4.00	7.00	10.00
Xylanase+Glucanase	0.10	0.10	0.10	0.10
Hybrid-6-phytase	0.10	0.10	0.10	0.10
Soy oil	28.15	29.30	30.16	31.02
Total	1000.00	1000.00	1000.00	1000.00

[1] Contains per kg of premix a minimum of 40 g Mn, 40 g Zn, 20 g Fe, 4.5 g Cu, 0.6 g I, 60 ppm Se, 3080000 IU vitamin A, 1100000 ICU vitamin D3, 6600 IU vitamin E, 4.4 mg B12, 330 mg of menadione, 2.64 g riboflavin, 0.44 g thiamine, 2.64 g D-pantothenic acid, 11 g niacin, 0.55 g vitamin B6, 275 mg folic acid, 154 g choline, 13.2 mg biotin.
[2] Sodium buffered formic acid
[3] NSP enzyme providing thermostable xylanase (min. 5600 TXU/g) and thermostable glucanase (min. 2500 TGU/g) activity.
[4] Hybrid-6-phytase providing min. 10000 FTU/g.

Jendza, et al., 2018

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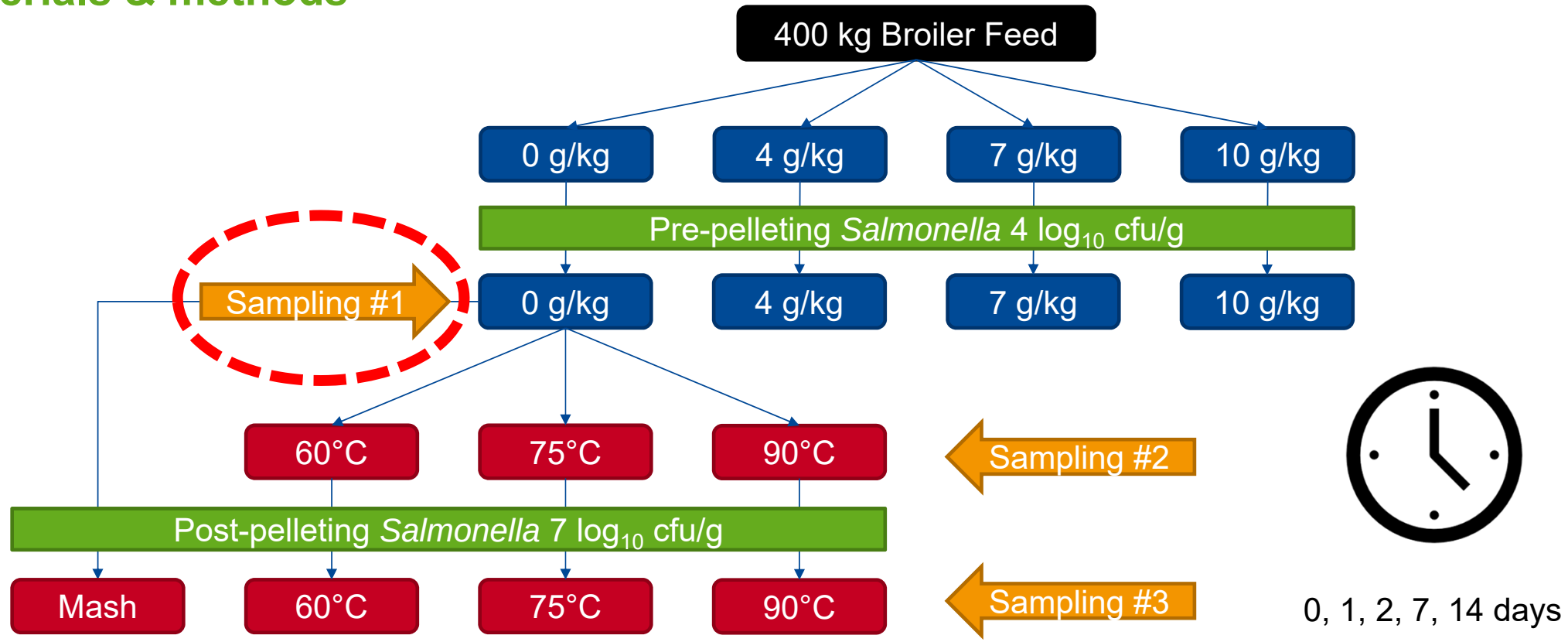
Study 1: Microbiology (KSU)

Materials & methods



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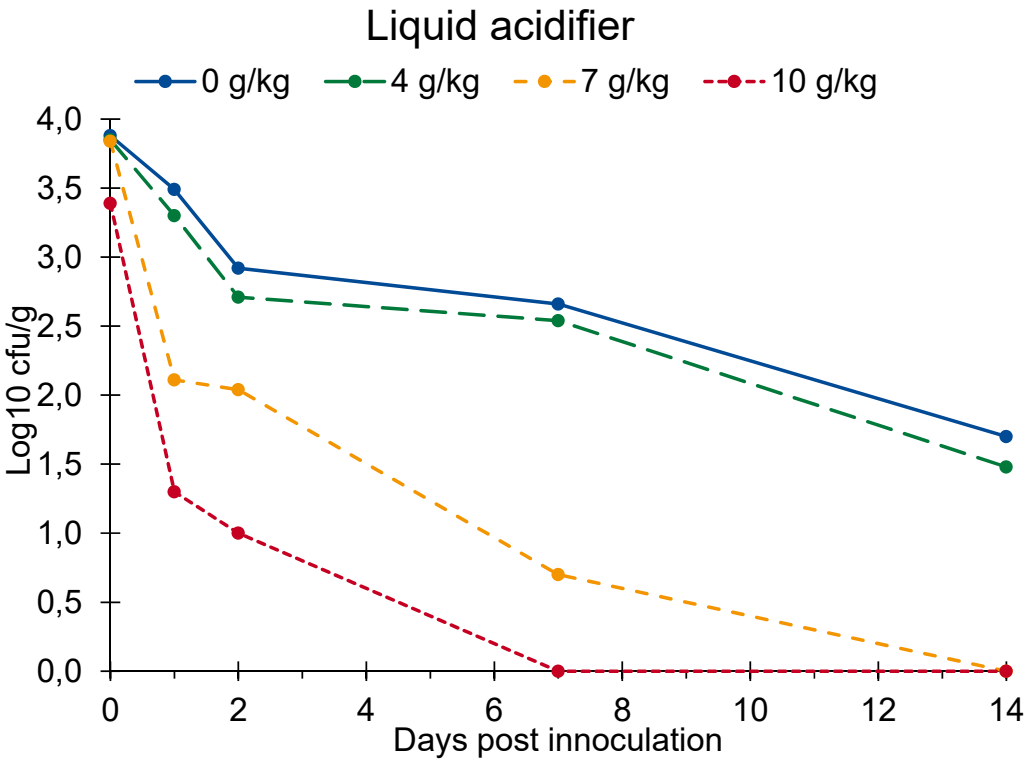
Microbiology: Results for pre-pelleting mash feed (Sampling #1)



- Numerical reductions in SE at each time point
- SE abundance half life of approximately 2 weeks in the absence of buffered formic acid
- SE becomes unculturable:
  - By day 14 at 7 g/kg buffered formic acid
  - By day 7 at 10 g/kg buffered formic acid

Jendza, et al., 2018

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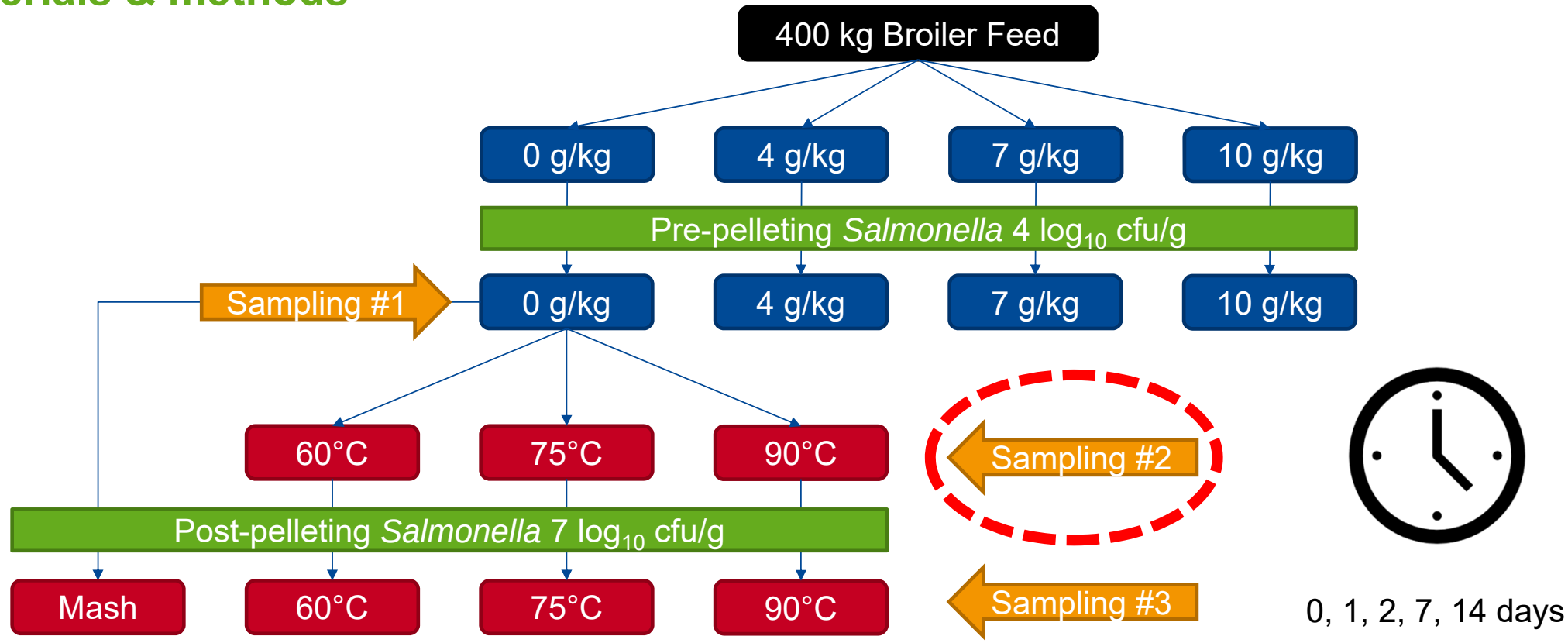
Study 1: Microbiology (KSU)

Materials & methods



Jendza, et al., 2018

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Microbiology: Results for pelleted samples (Sampling #2)

g/kg	°C	Day 0	Day 1	Day 2	Day 7	Day 14
0	Mash	3.9	3.5	2.9	2.7	1.7
0	60	+	+	-	n/a	-
0	75	-	-	-	n/a	-
0	90	-	-	-	n/a	-
4	Mash	3.9	3.3	2.7	2.5	1.5
4	60	+	+	-	n/a	-
4	75	-	-	-	n/a	-
4	90	-	-	-	n/a	-
7	Mash	3.8	2.1	2.0	0.7	-
7	60	+	+	-	n/a	-
7	75	-	-	-	n/a	-
7	90	-	-	-	n/a	-
10	Mash	3.4	1.3	1.0	-	-
10	60	-	-	-	n/a	-
10	75	-	-	-	n/a	-
10	90	-	-	-	n/a	-

- 60°C for 45 sec
  - Unquantifiable on day 0
  - Detectable on days 0 and 1, but not day 2
- 75°C for 45 sec
  - Undetectable on day 0
- 90°C for 45 sec
  - Undetectable on day 0
  - No apparent benefit to SE control to higher temperature

Jendza, et al., 2018

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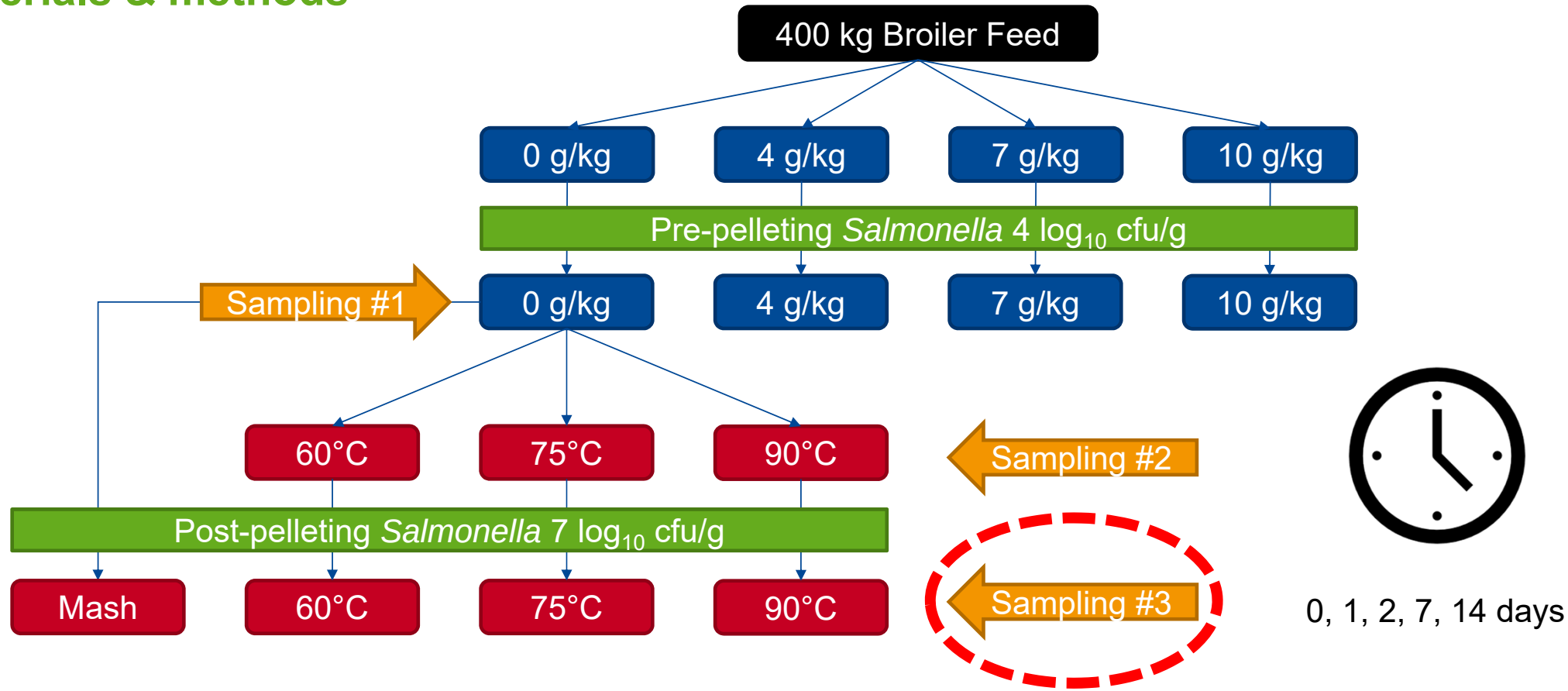
Study 1: Microbiology (KSU)

Materials & methods



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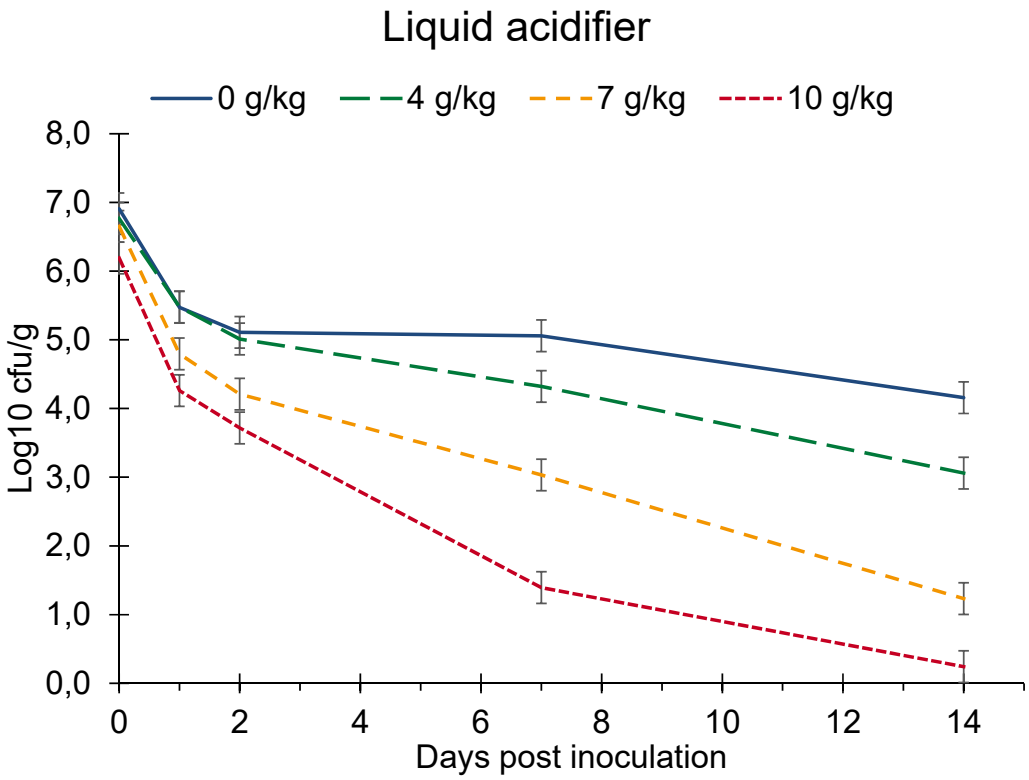
Microbiology: Results for reinoculated pellets (Sampling #3)



- No effect of conditioning temperature on resistance to recolonization by SE
- Clear Dose × Time effect on SE counts
- Up to 4 log10 cfu/g reduction at 10 g/kg of buffered formic acid

Jendza, et al., 2018

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Study 1: Conclusions

1. Do higher conditioning temperatures actually improve SE control?
   - Marginal benefit of 75°C over 60°C
   - No apparent benefit from 75°C to 90°C

2. Can acidification enable lower pelleting temperatures?
   - Yes! - no detectable SE with 1% BFA and 60° conditioning

3. Which intervention is better suited to mitigating risks from SE contamination?
   - Pelleting was an excellent immediate kill step, but no protection against re-inoculation
   - Acidification with BFA imposed continuous pressure on SE counts

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STUDY 2

Massey Univ., NZ

Effect of feed acidification and conditioning temperature on nutrient digestibility and performance of broiler starters fed wheat-based pelleted diets - Abdollahi, et al., 2018

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Study 2: Bird performance, digestibilities and pellet durability

- Aim:
  - Identify possible approaches to improve feed hygiene while maintaining high pellet durability at low conditioning temperatures

- Objective of study:
  - Investigate the influence of a liquid feed acidifier and conditioning temperature on broiler growth performance and ileal nutrient digestibility

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Study 2: Bird performance, digestibilities and pellet durability

Materials and methods

- 3 × 2 factorial arrangement of treatments
  - 3 inclusion levels of liquid feed acidifier (buffered formic acid*) at 0, 7 and 10 g/kg
  - 2 conditioning temperatures of 60°C and 90°C

- Wheat-soy based broiler diets (exact same diets mixed as in the KSU study)
- Conditioning time was 30 seconds and the conditioning temperature was measured at the outlet of the conditioner

- 288 male broilers (Ross 308), 6 treatments, 6 replicates/treatment, 8 birds/cage
- Body weights and feed intake were recorded at weekly intervals
- Determination of ileal digestibility on d 21 using titanium dioxide (5 g/kg) as an indigestible marker

- Pellet durability Index (PDI) was determined in a Holmen Pellet Tester

* Buffered formic acid = formic acid + sodium formate

Abdollahi, et al., 2018

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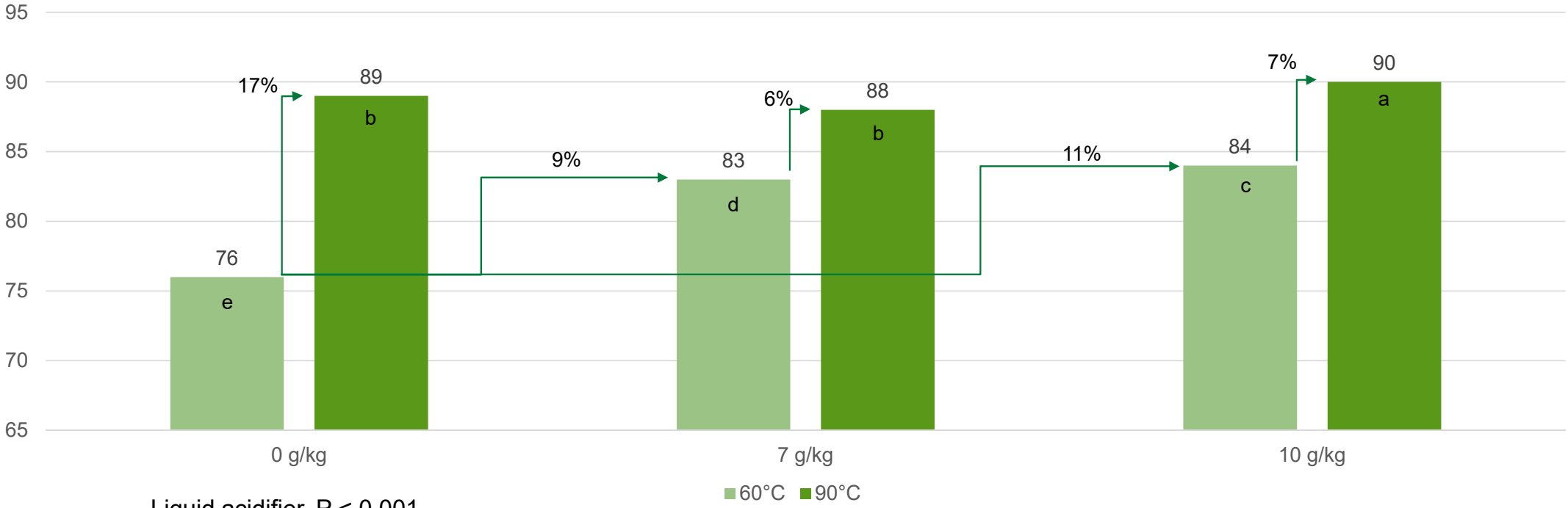
Effect of acidifier inclusion and conditioning temp on pellet durability (PDI, %)



Liquid acidifier, P < 0.001
C Temp, P < 0.001
Liquid acidifier × C Temp, P < 0.001

Abdollahi, et al., 2018

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Influence of acidifier inclusion and conditioning temperature on growth performance

Acidifier g/kg	Cond. Temp °C	Weight gain g	Feed intake g		FCR
None	60	1022	1351	1358	1.333
	90	1029	1364		1.330
7	60	1061	1389	1380	1.310
	90	1033	1370		1.333
10	60	1049	1394	1398	1.337
	90	1043	1401		1.344
P - value					
Acidifier		0.207	0.066		0.246
C. Temp		0.422	0.984		0.321
Interaction		0.417	0.598		0.531

Abdollahi, et al., 2018

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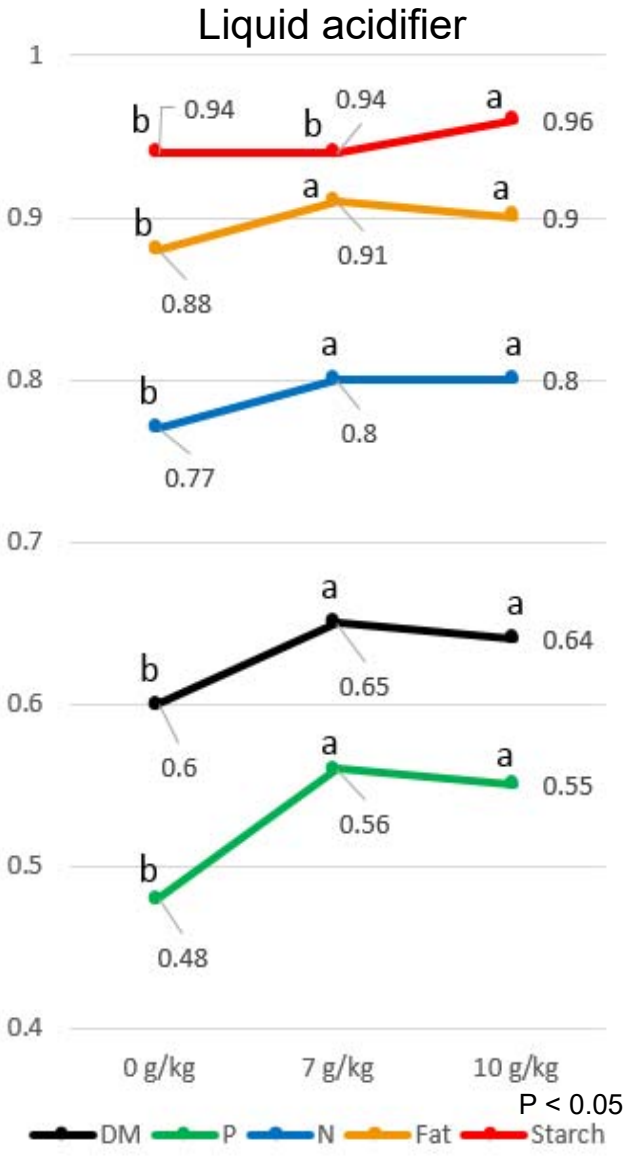

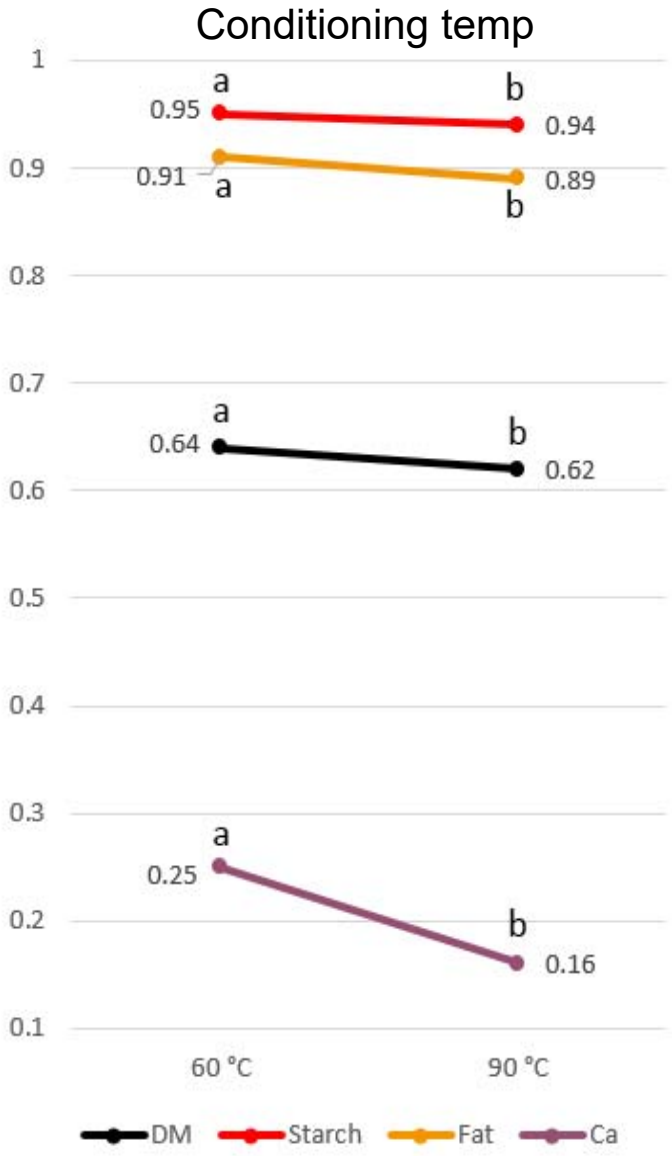

Effects of liquid acidifier inclusion and conditioning temperature on ileal digestibility of nutrients in pelleted diets

Abdollahi, et al., 2018

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Study 2: Conclusions

- Feed acidification, through inclusion of organic acids, is beneficial to nutrient digestibility in broilers fed pelleted diets
- Application of high conditioning temperatures during poultry feed manufacture, to achieve high pellet quality and feed safety, does not favour nutrient utilisation
- Considering the negative impact of high conditioning temperatures on nutrient digestibility, there is a need to find new approaches to improve feed hygiene and pellet quality which are not detrimental to feed nutrients

Abdollahi, et al., 2018

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Recommendations

- Pellet at the lowest reasonable temperature
  - Provides instantaneous decontamination, regardless of conditioning temperature
  - Save on energy costs
  - Preserve nutritional value (Maillard reaction, etc.)

- Acidify with a buffered formic acid
  - Support decontamination via pelleting
  - Protect against recontamination throughout your feed manufacture and -delivery system
  - Focus on inclusion levels: qualitative (it's in) vs quantitative (it works)

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Acknowledgements

- A Huss & C Jones, Kansas State University, USA – Microbiology study
- MR Abdollahi & F Zaefarian, Massey University, NZ – Digestibility & Performance study
- JA Jendza, BASF Corporation, USA – Global Technical Manager: Organic Acids

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References

- https://goo.gl/iFifwS