Feed Mill Research Update: Pelleting





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Pelleting

Purpose

- Palatability
- Animal performance
- Feed handling

- Feed wastage
- Selective feeding
- Ingredient segregation
- Pathogenic organisms





- Conditioning Temperature
- Steam Pressure
- Retention time
- Moisture
- Die thickness

What influences the cost of pelleting?

Cost

- Labor Cost
  - $/ton
  - Employee hrs/ton
- Boiler Fuel
  - $/ton
  - BTU/ton
- Electrical Energy
  - $/ton
  - $/kwh
- Roll and die cost

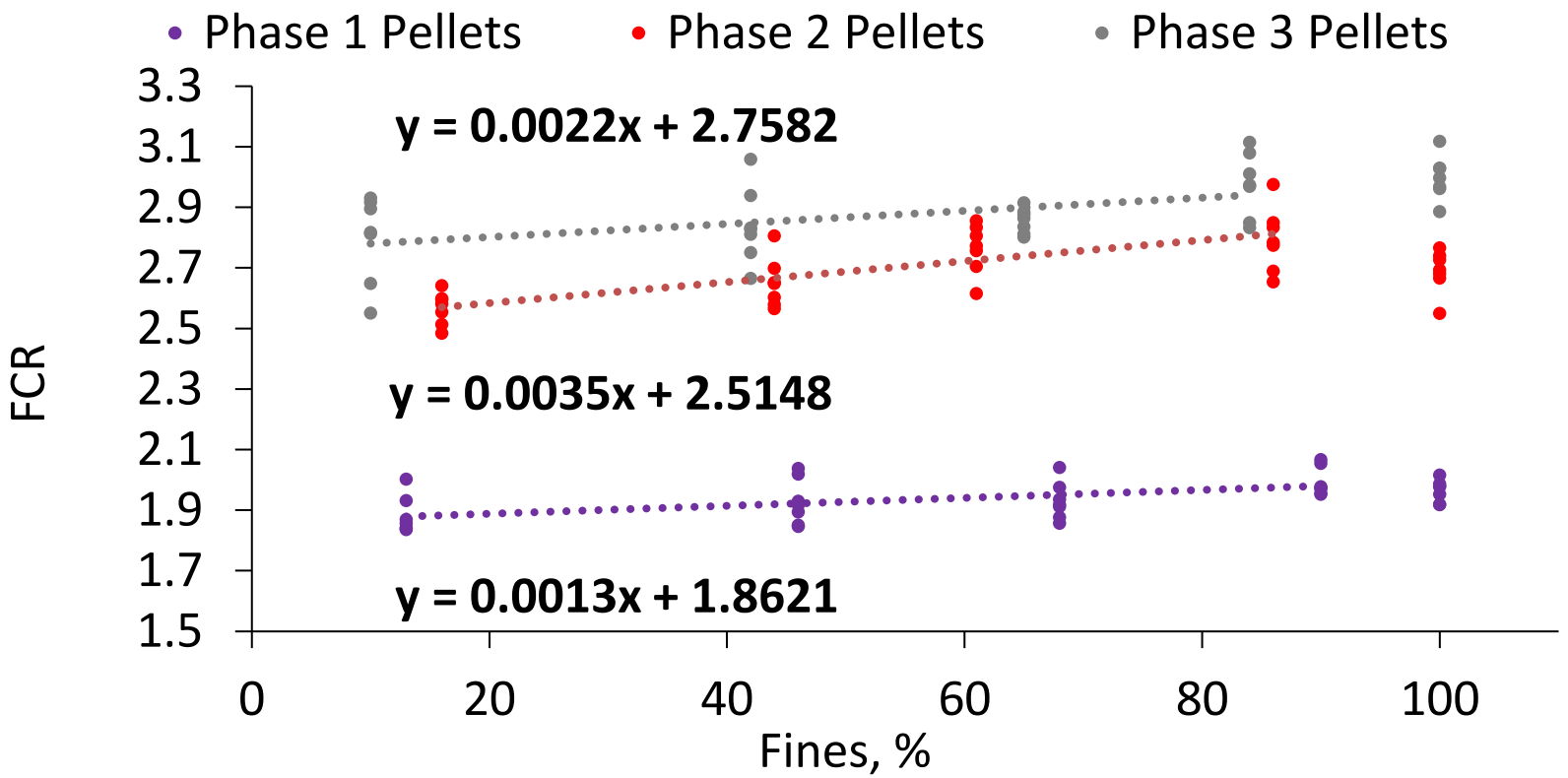
Key Performance Indicators

- Tons per run
- Changeovers
- Die plugs
- Recycled fines

Factors that Affect Pellet Quality

- Diet
  - Added fat level
  - Protein
  - DDGS inclusion
  - Ground corn particle size
- Conditioning Temperature
- Conditioning Retention Time (30 sec. vs. 60 sec.)
- Production Rate
- Die L:D ratio

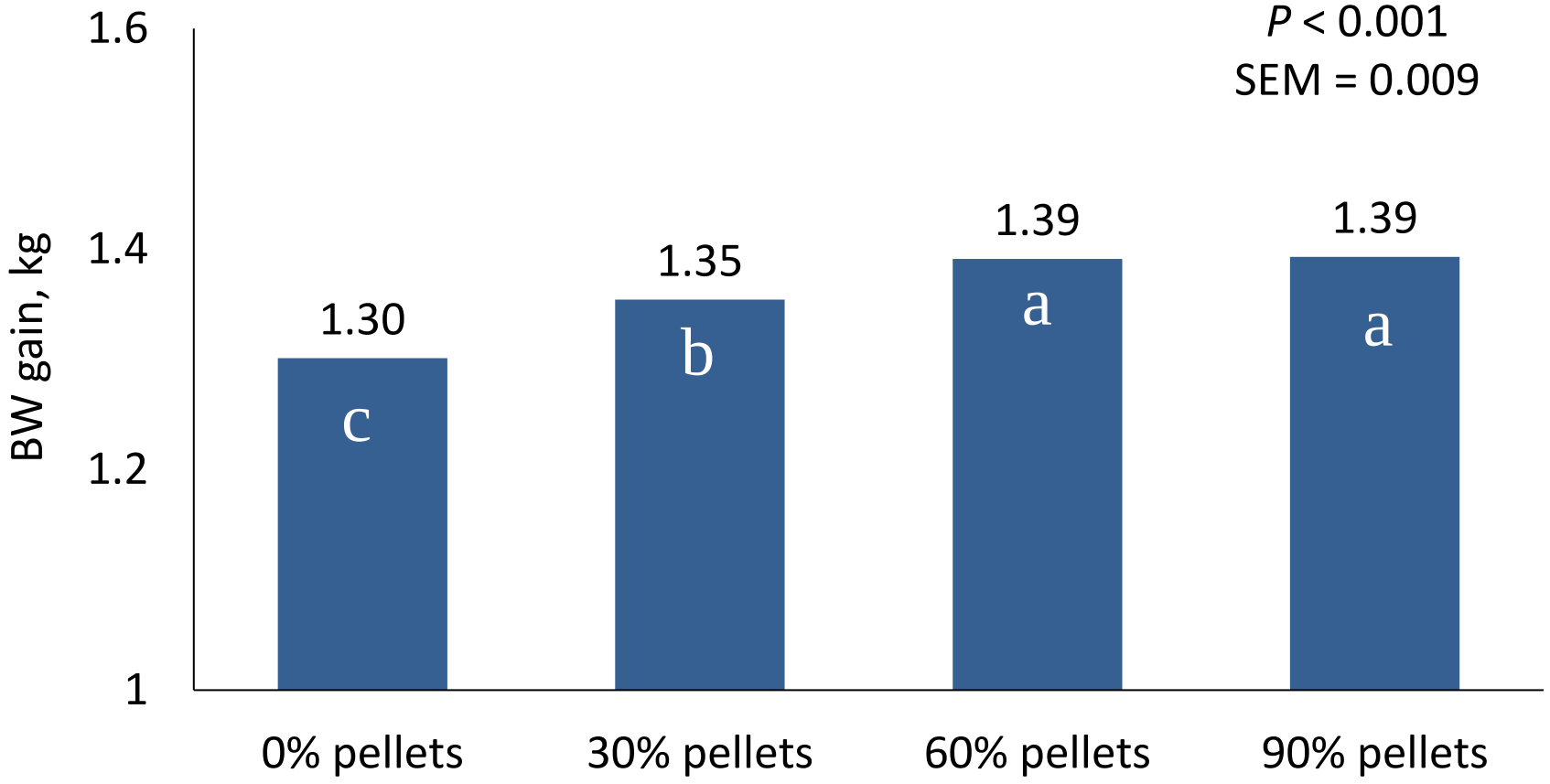
Percent Fines in Swine Diets



Wt Range	Screened pellets vs mash	10% fines reduction
43-68 kg	4.1	0.013 (0.7%)
81-107 kg	4.5	0.035 (1.4%)
118-144 kg	6.7	0.02 (0.7%)

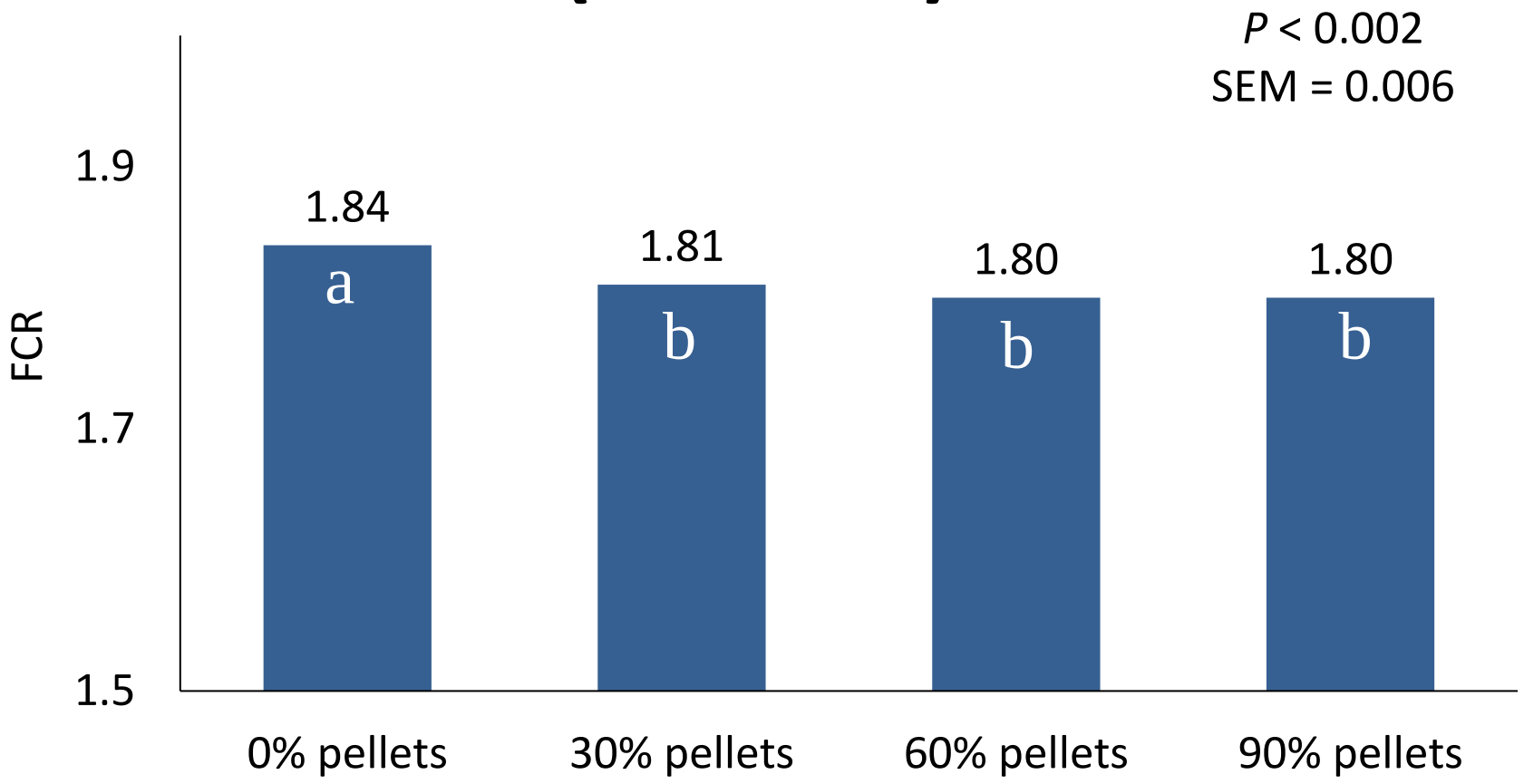
Badger et al., 2023

Pellet Fines on Broilers Performance (21-38 d)



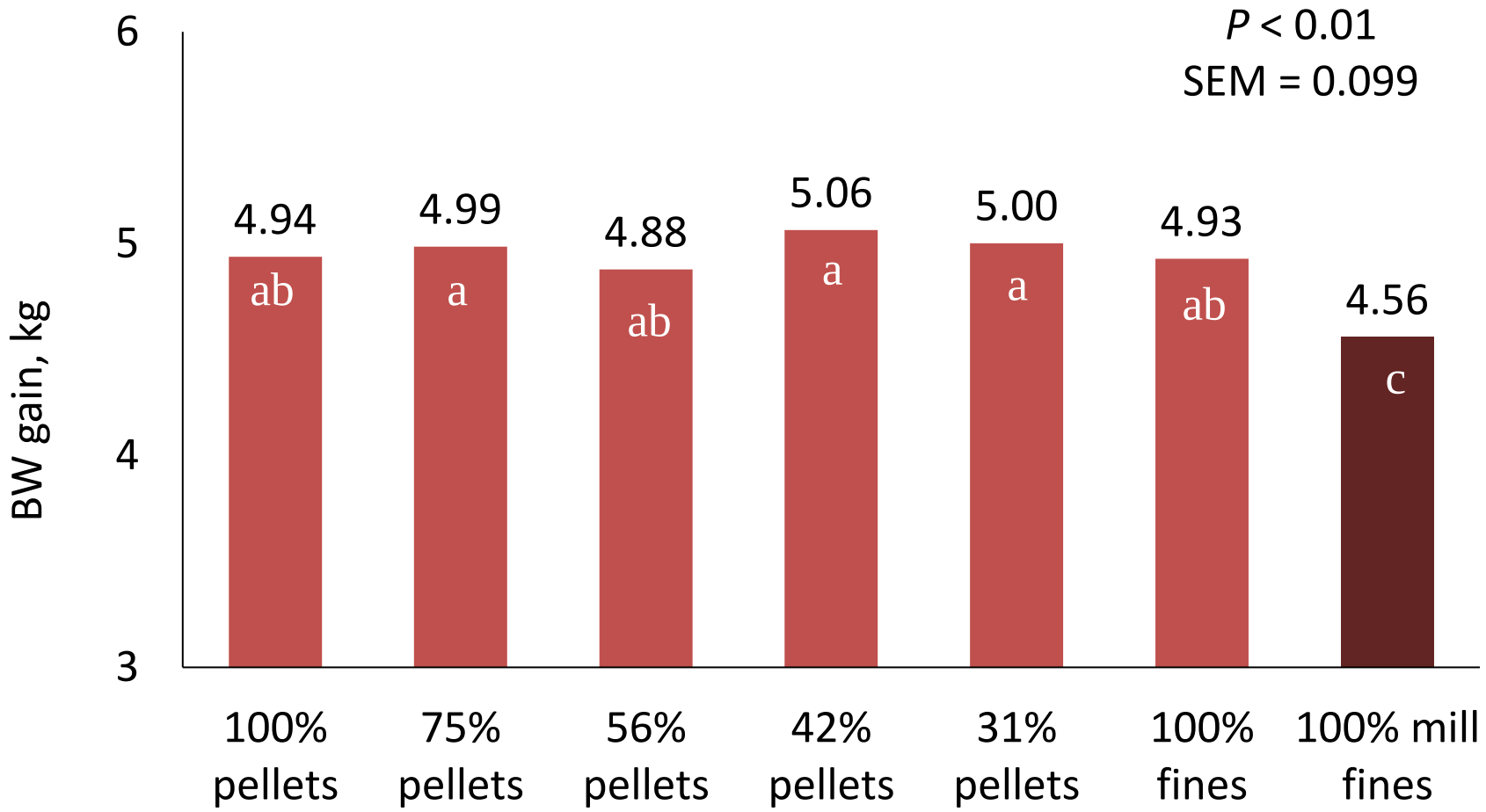
Lilly et al., 2011

Pellet Fines on Broilers Performance (21-38 d)



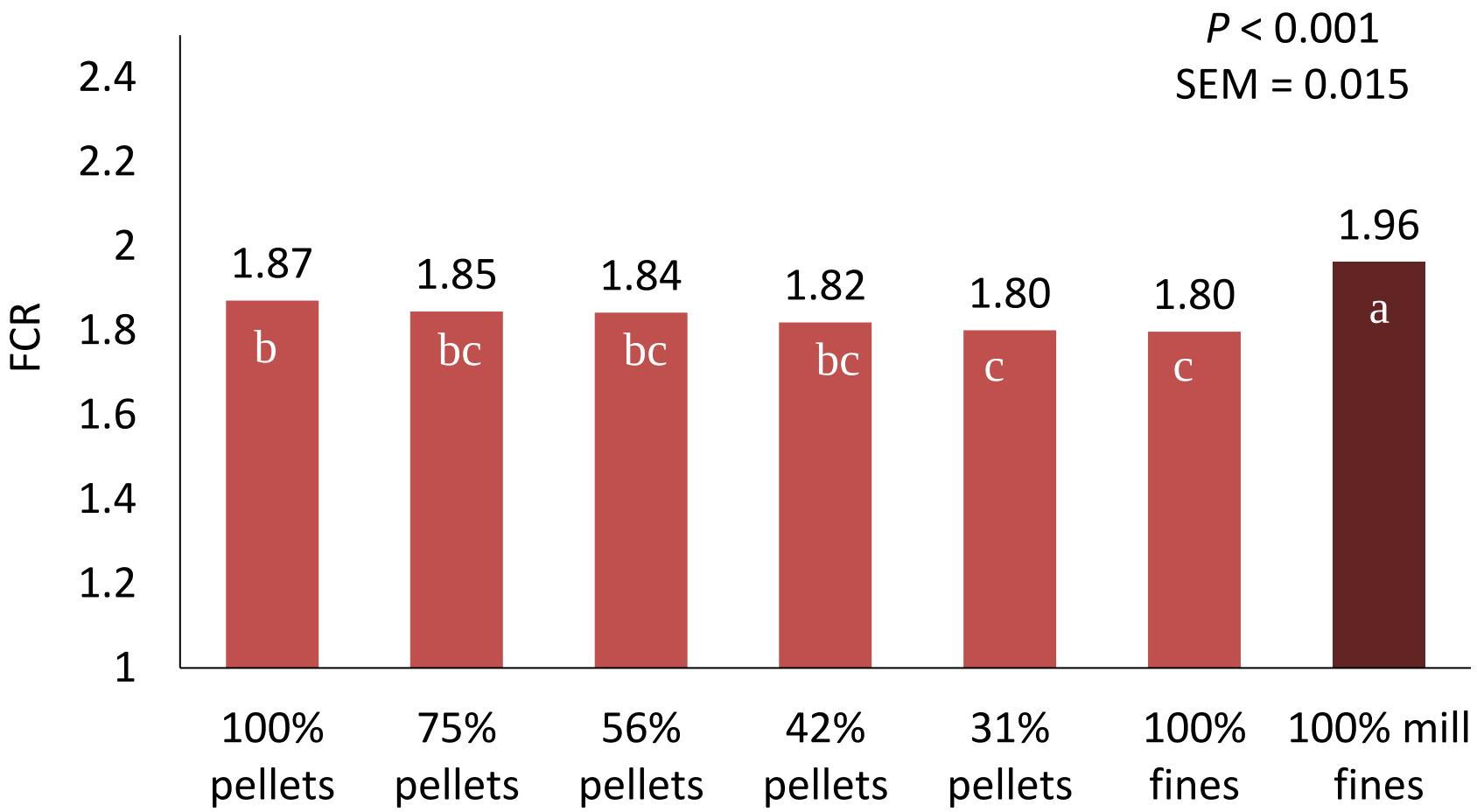
Lilly et al., 2011

Pellet Fines on Broilers Performance



McCafferty et al., 2023

Pellet Fines on Broiler Performance



Diet Formulation and Ingredients Influence on the Pelleting Process

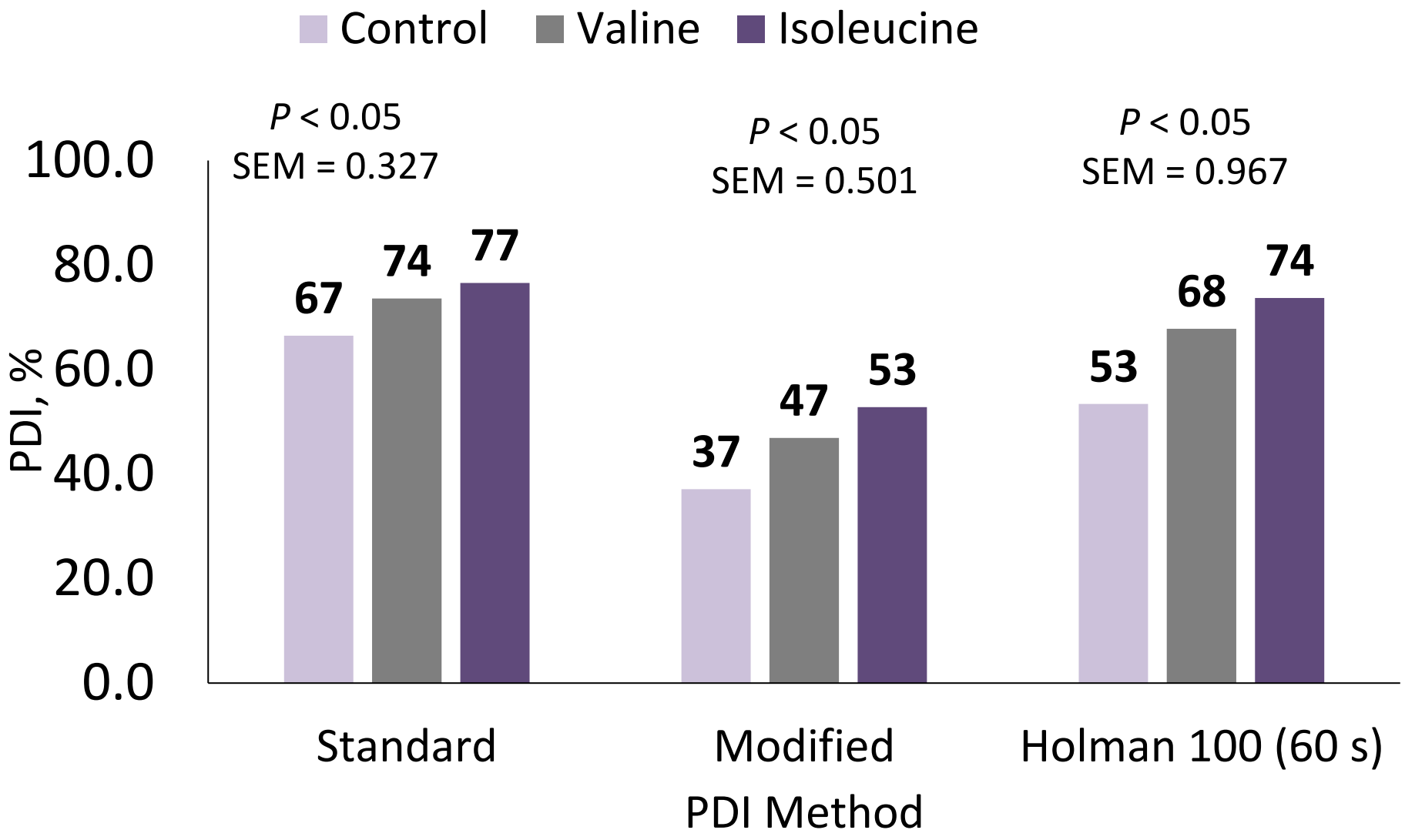
- Protein content
- Fat/oil content
- Fiber content
- Ingredient Variability
- Abrasiveness



Diet Formulation

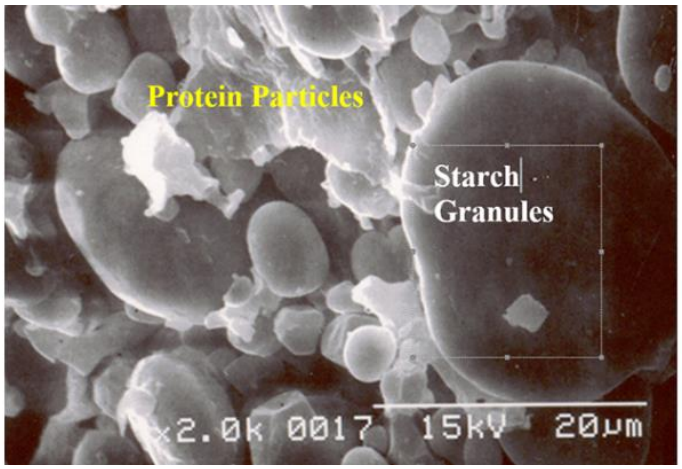
Item, %	Control	Val	Val + Ile
Corn	**54.20**	**56.44**	**57.48**
Soybean Meal	**39.12**	**37.13**	**36.16**
CWG	**2.52**	**2.11**	**1.92**
Limestone	1.11	1.12	1.12
Dicalcium P	1.81	1.83	1.84
Salt	0.34	0.35	0.35
Copper sulfate	0.05	0.05	0.05
L-Lys	0.15	0.22	0.24
L-Met	0.31	0.32	0.33
L-Thr	0.10	0.12	0.14
L-Val	**---**	**0.03**	**0.05**
L-Ile	**---**	**---**	**0.02**
VTM	0.30	0.30	0.30
Total	100	100	100
Calculated nutrient analysis			
MEn, kcal/lb	**1,380**	**1,380**	**1,380**
Crude protein, %	24.43	23.73	23.40
Crude fat, %	4.95	4.60	4.44

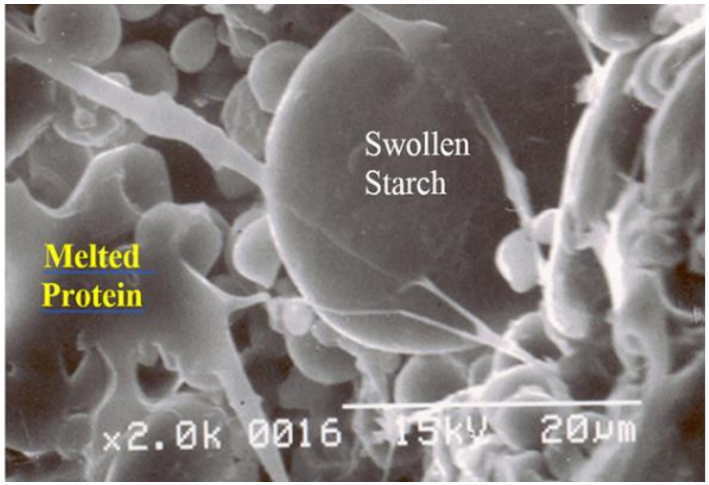
Pellet Durability Index

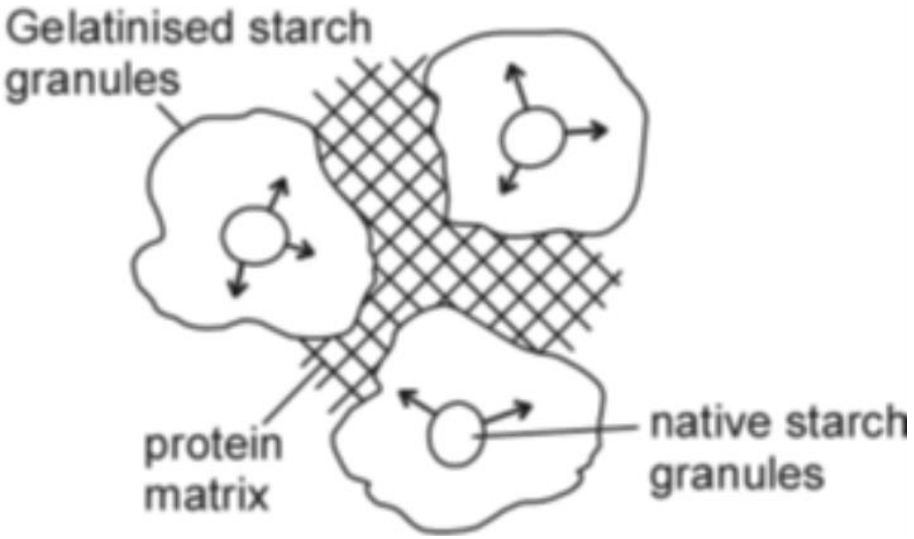


Dunmire et al., 2019

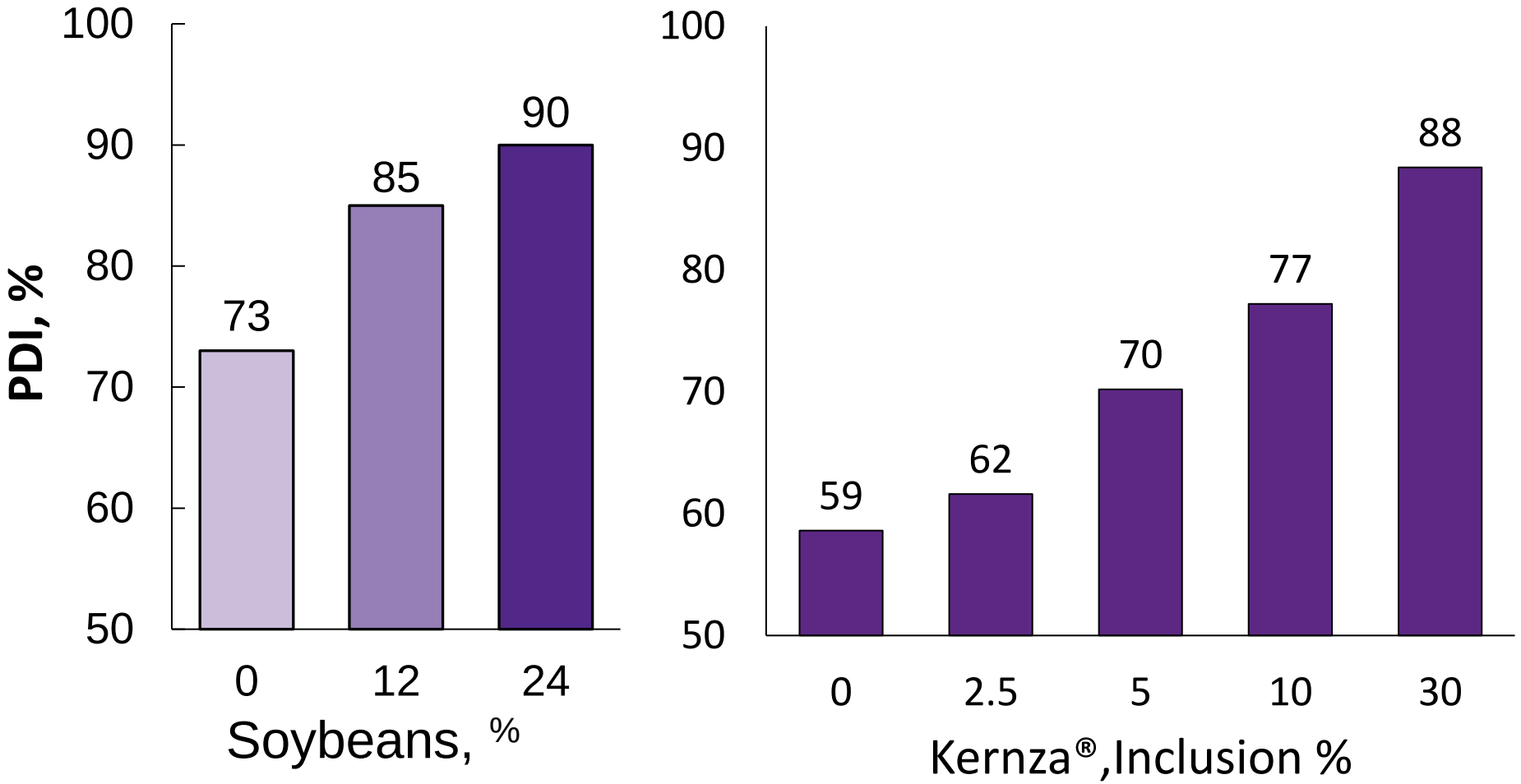
Proteins


Protein Particles
Starch
Granules
x2.0k 0017 15kV 20µm


Swollen
Starch
Melted
Protein
x2.0k 0016 15kV 20µm


Gelatinised starch
granules
protein
matrix
native starch
granules

Protein Source: Pellet Durability Index

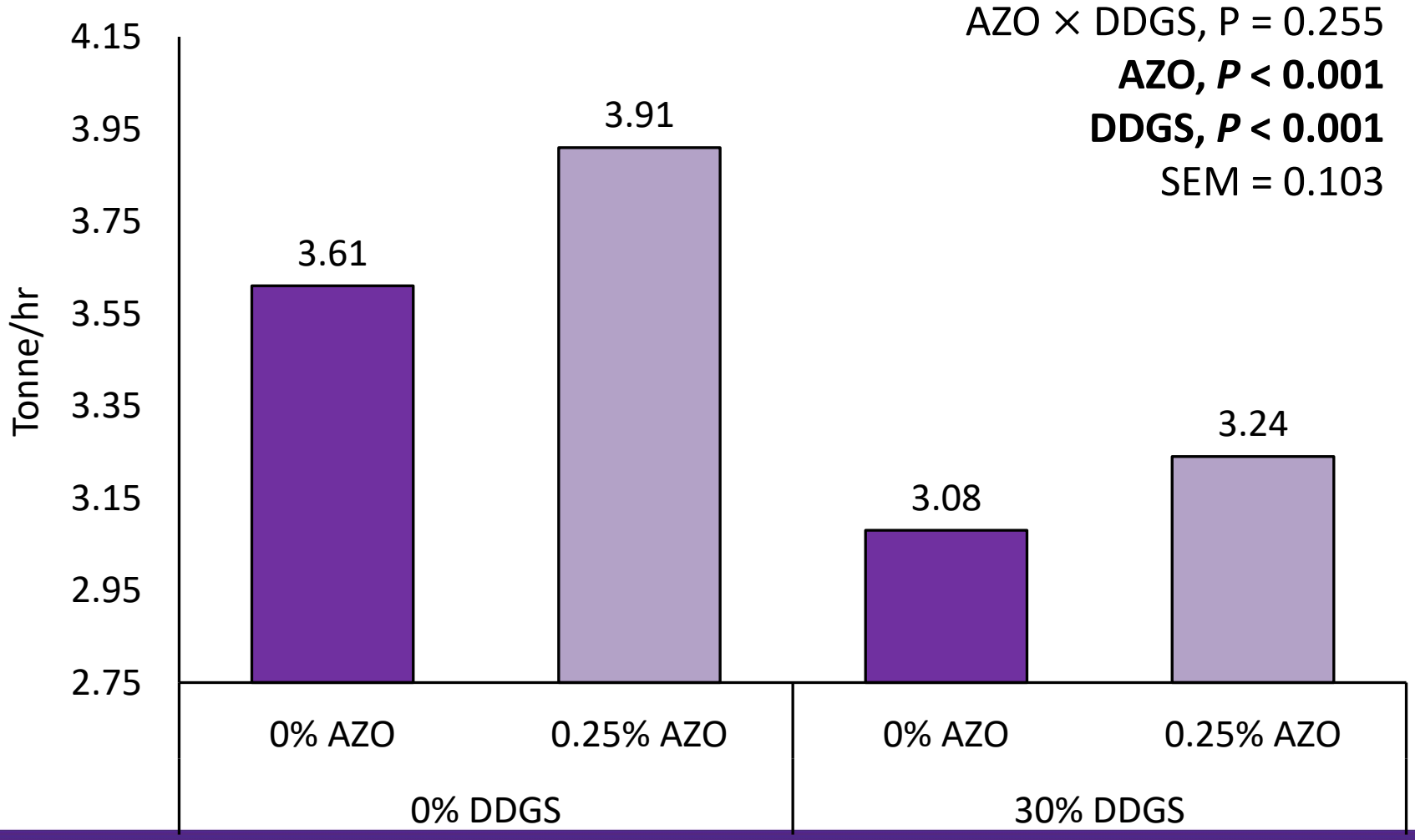


Evans et al, 2020; Friesen et al., 2023

DDGS: Pellet Mill Throughput

50-hp CPM, 3016-4; L:D 8.75

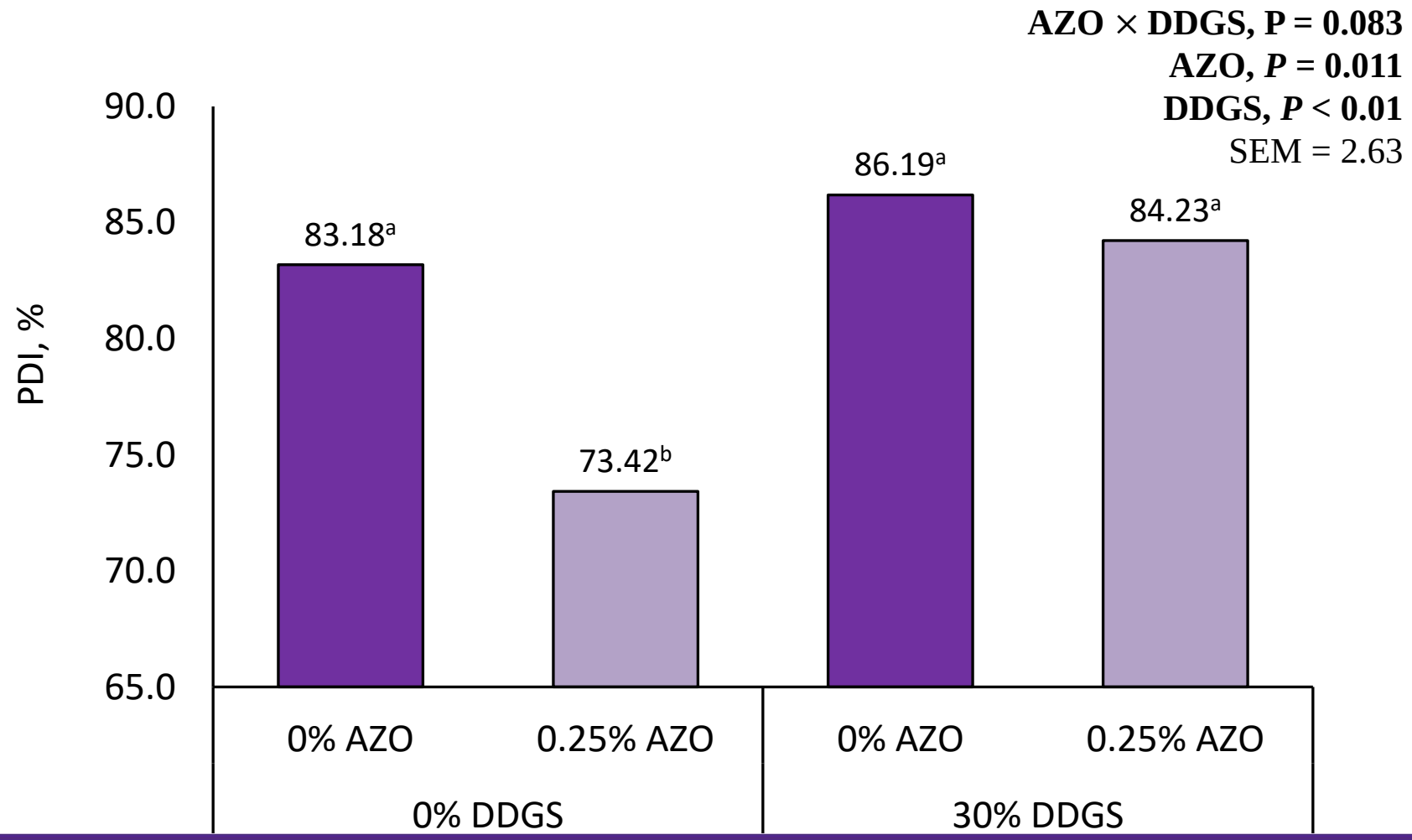
Pellet mill motor load held constant



Badger et al., 2023

DDGS: Pellet Durability Index

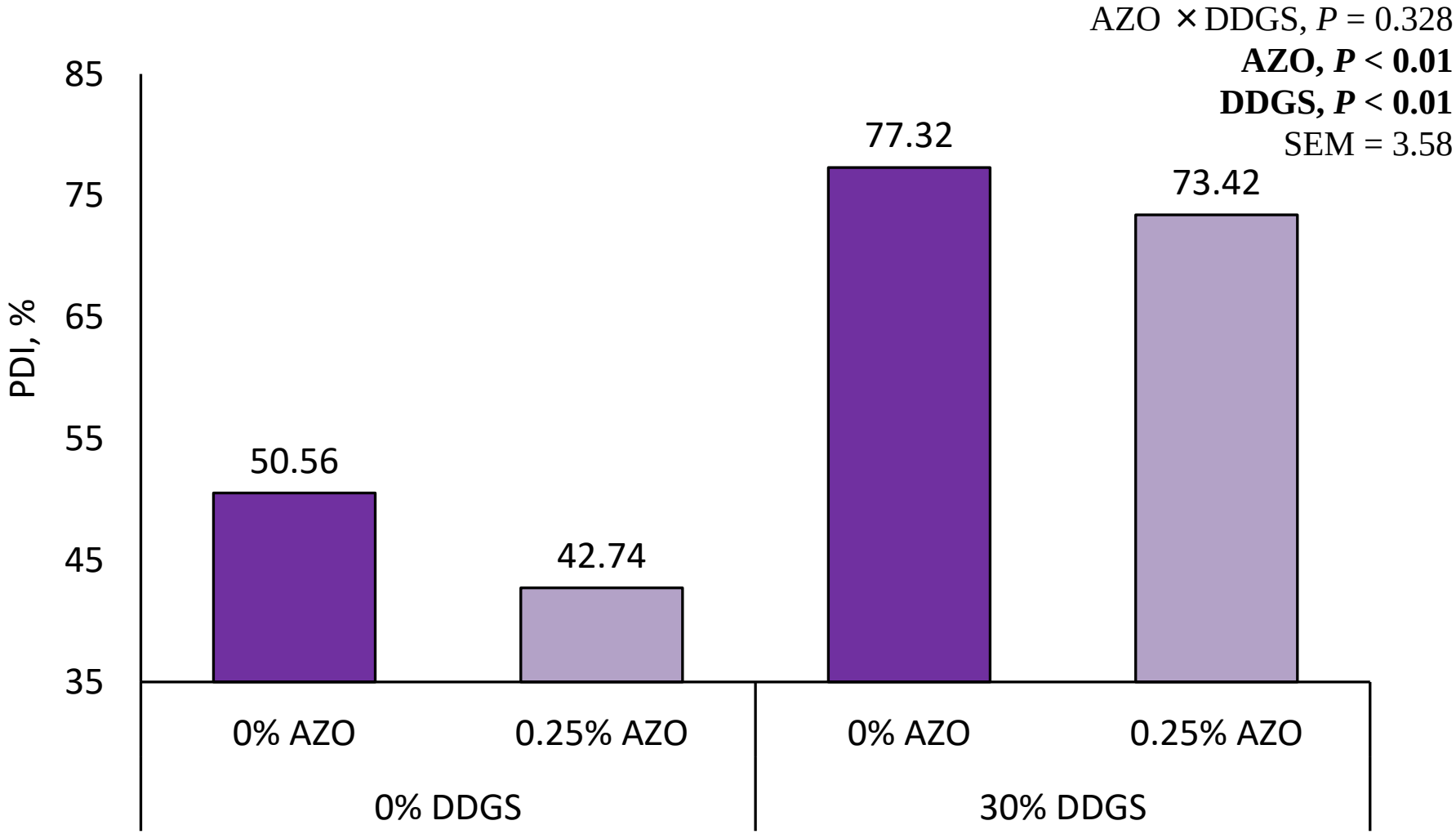
50-hp CPM, 3016-4; L:D 8.75
Pellet mill motor load held constant



Badger et al., 2023

DDGS: Pellet Durability Index

500-hp Andritz 32-700; LD 8.9
Production rate held constant



Badger et al., 2023

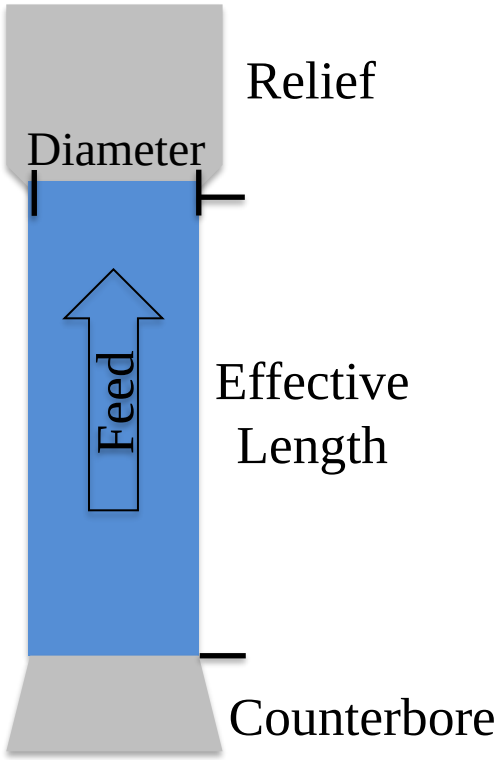
Pellet Mill Parameters

- Equipment: die specifications
- Settings: temperature, conditioning time and throughput

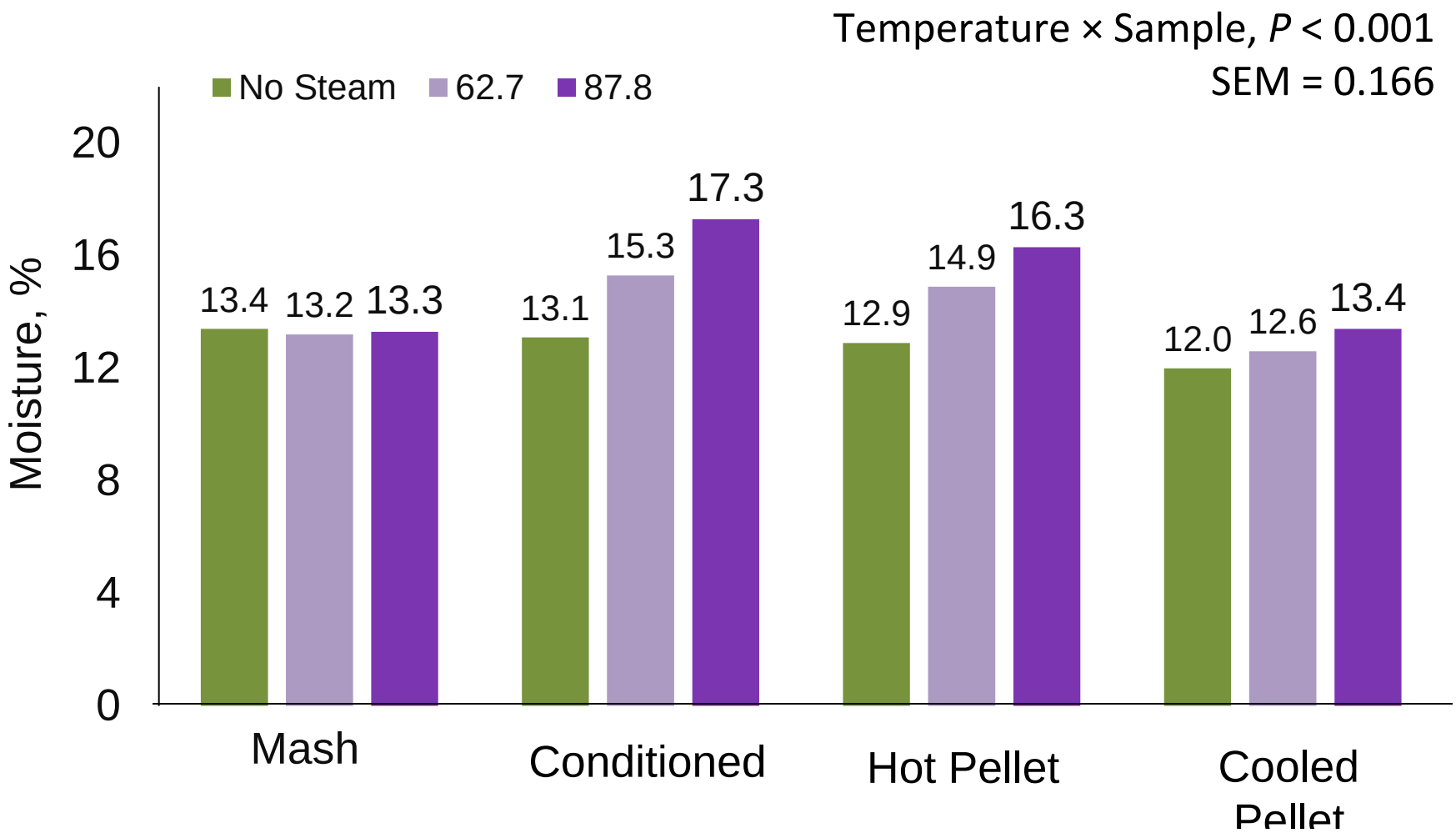






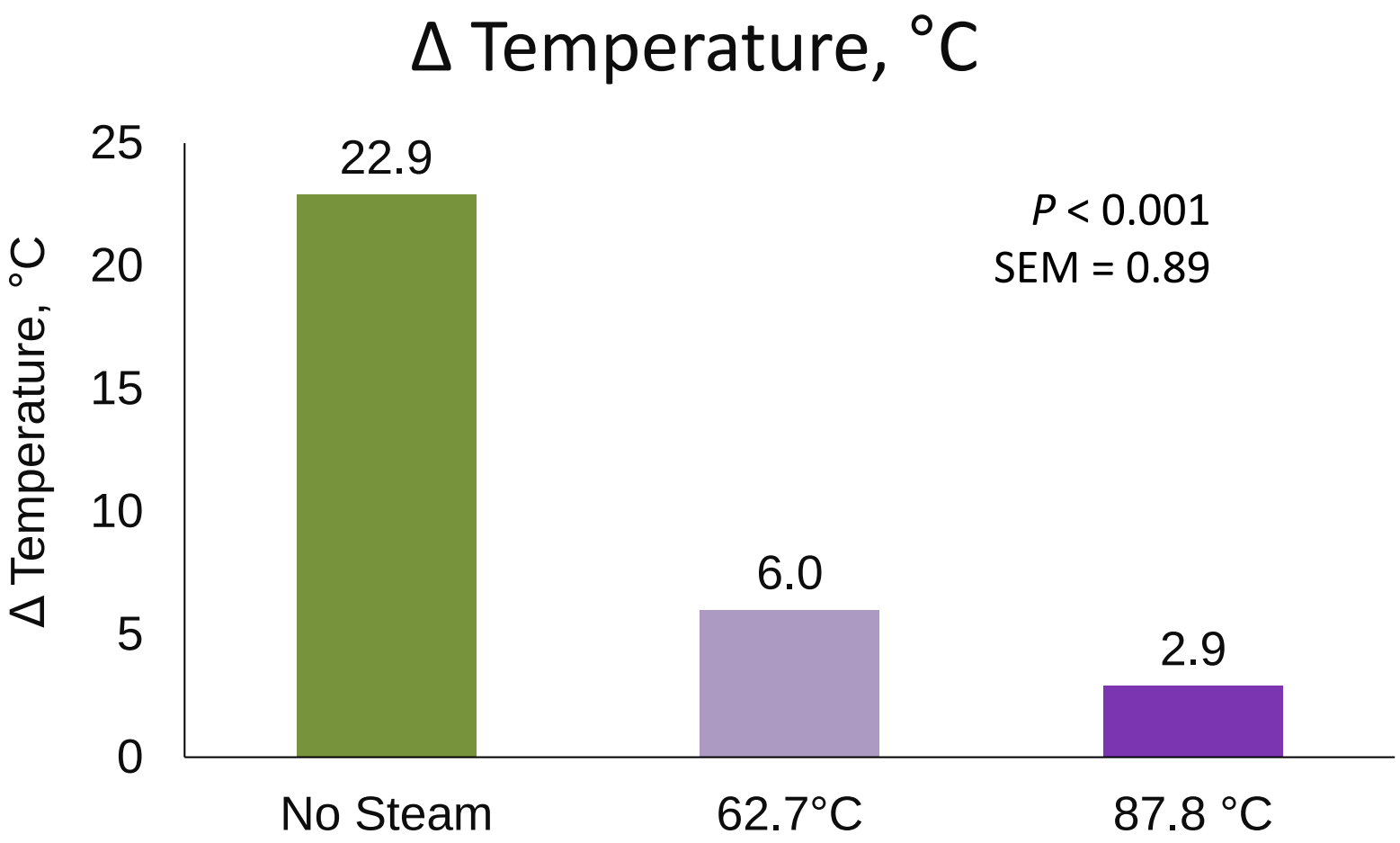


Conditioning Temperature



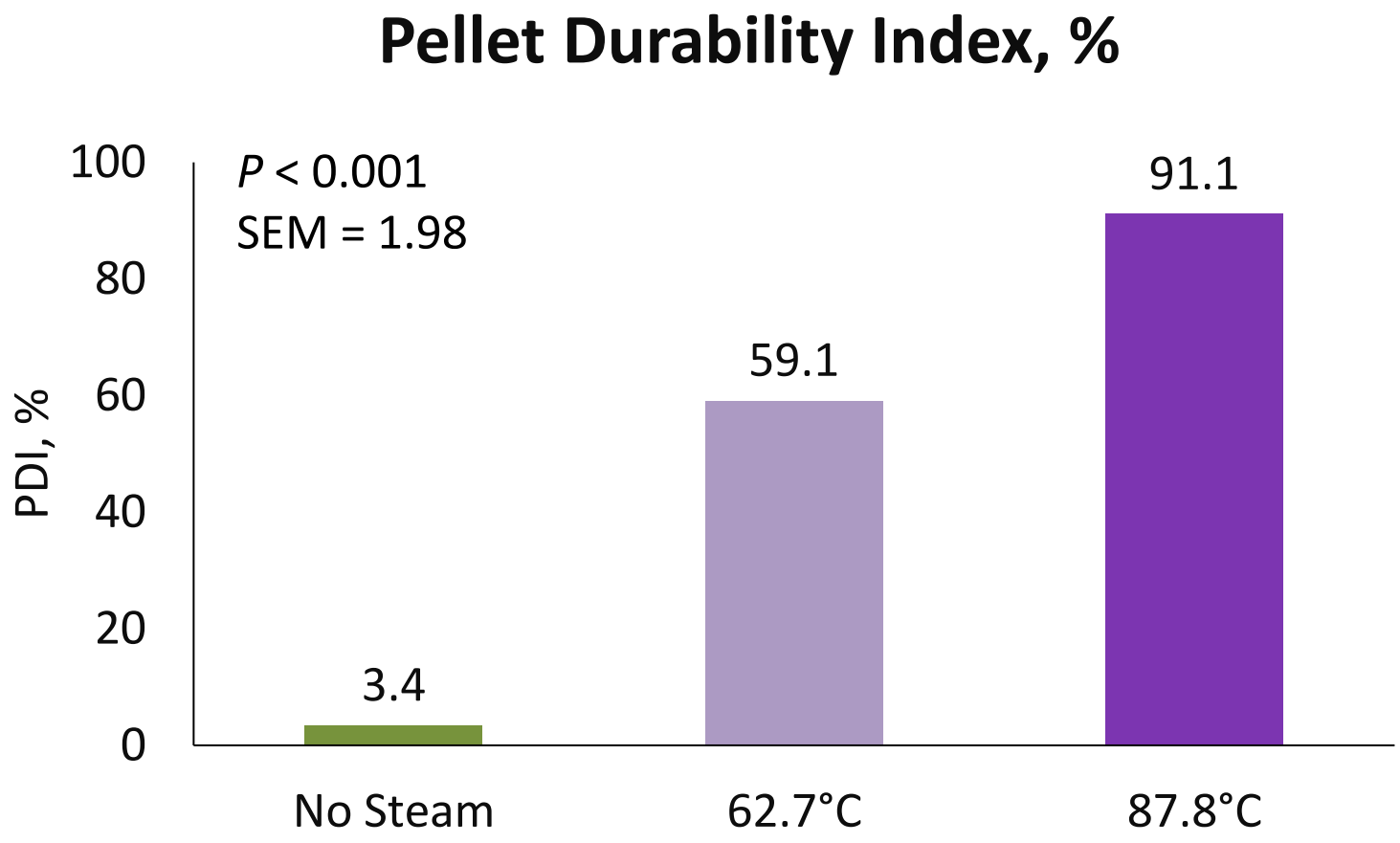
Kort et al., 2020

Conditioning Temperature



Kort et al., 2020

Conditioning Temperature



Kort et al., 2020

Effects of Low Conditioning Temperature

- Increases die wear
- Requires more energy
- Reduces throughput
- Increase in HPT due to frictional heat between the die and feed/pellet surface
- Increases fines





Conditioning Temperature

Table 3. Pellet Durability Index (PDI), Pellet Hardness and Percentage of Fines of the Experimental Diets.

	Treatments[1]						*P*-value	
	P50	P60	P70	P80	P90	SEM	L	Q
PDI (%)[2]	78.8	79.0	85.4	87.4	91.4	1.02	<0.010	0.249
Fines (%)	4.49	4.53	4.70	5.12	5.20	0.117	0.734	0.922
Hardness (kgf)[3]	4.32	4.42	5.56	6.26	7.53	0.249	<0.010	0.231

[1]M: mash diet; P50: pelleted diet, not conditioned; P60: pelleted diet conditioned at 60°C; P70: pelleted diet conditioned at 70°C; P80: pelleted diet conditioned at 80°C; P90: pelleted diet conditioned at 90°C.

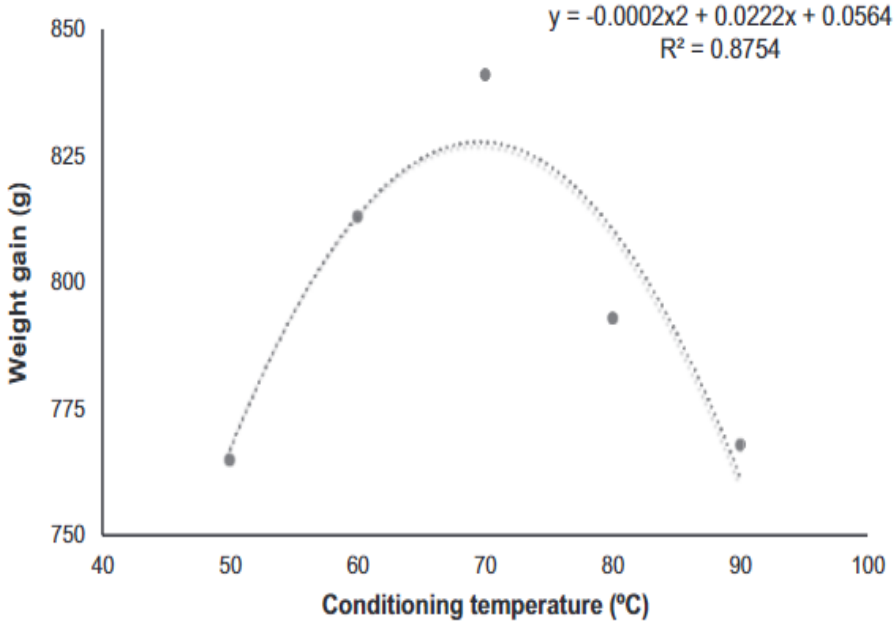
[2]Linear effect of conditioning temperature. $Y = 0.3352x + 60.984$; $R^2 = 0.94$.

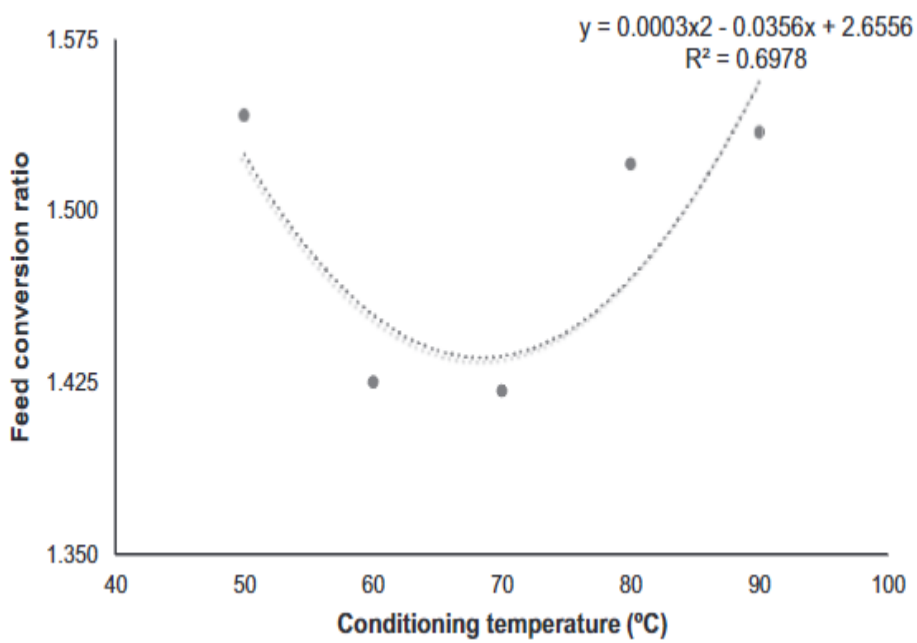
[3]Linear effect of conditioning temperature. $Y = 0.0826x–0.1606$; $R^2 = 0.91$.

L: linear; Q: quadratic.

Teixeira Netto et al., 2022

Conditioning Temperature





- 68°C optimal conditioning temperature for weight gain
- 67°C optimal conditioning temperature for FCR

Teixeira Netto et al., 2022

Conditioning Temperature

Table 5. Coefficient Ileal Apparent Digestibility of Dry Matter (CIADDM), Crude Protein (CIADCP), and Starch (CIADstarch), Coefficient of Apparent Metabolizability of Dry Matter (CAMDM) Apparent Metabolizable Energy Content (AME) of the Experimental Diets.

	Treatments[1]							*P*-value	
	M	P50	P60	P70	P80	P90	SEM	L	Q
CIADDM (%)[2]	69.84	68.90	72.31	71.61	73.62	76.62*	0.549	<0.001	0.775
CIADCP (%)[5]	76.30	72.35	78.25	77.39	79.14	79.98	0.602	<0.001	0.078
CIADstarch (%)[4]	93.2	91.8	93.3	92.1	93.7	94.4	0.398	0.012	0.661
CAMDM (%)[3]	75.85	72.30*	76.59	77.77	79.18*	79.47*	0.548	<0.001	0.008
AME (kcal/kg of DM)[6]	3,764	3,592*	3,770	3,879	3,897*	3,933*	30.4	<0.001	0.003

[1]M: mash diet; P50: pelleted diet, not conditioned; P60: pelleted diet conditioned at 60°C; P70: pelleted diet conditioned at 70°C; P80: pelleted diet conditioned at 80°C; P90: pelleted diet conditioned at 90°C.

[2]Linear effect of conditioning temperature ($P = 0.000$). $Y = 0.1675x + 60.888$; $R^2 = 0.47$.

[3]Quadratic effect of conditioning temperature ($P = 0.008$). $Y = -0.0055x^2 + 0.9452x + 39.158$; $R^2 = 0.850$.

[4]Linear effect of conditioning temperature ($P = 0.012$). $Y = 0.0585x + 88.923$; $R^2 = 0.15$.

[5]Linear effect of conditioning temperature ($P = 0.0003$). $Y = 0.1614x + 66.122$; $R^2 = 0.15$.

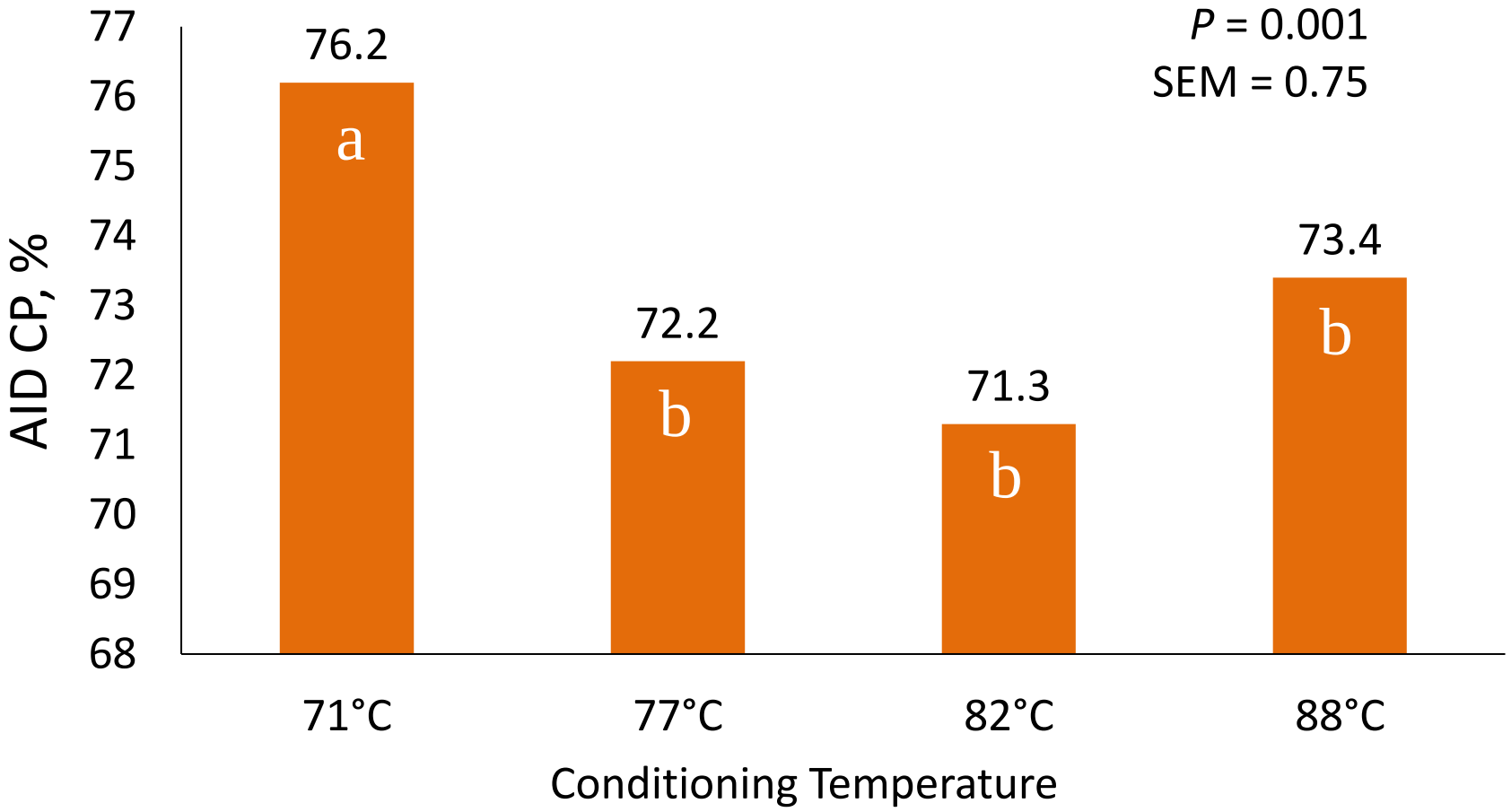
[6]Quadratic effect of conditioning temperature ($P = 0.003$). $Y = -0.0036x^2 + 2.2155x + 2969.3$; $R^2 = 0.952$.

*Indicates difference compared with the mash diet by Dunnett's test ($P \leq 0.05$).

L: linear; Q: quadratic.

Teixeira Netto et al., 2022

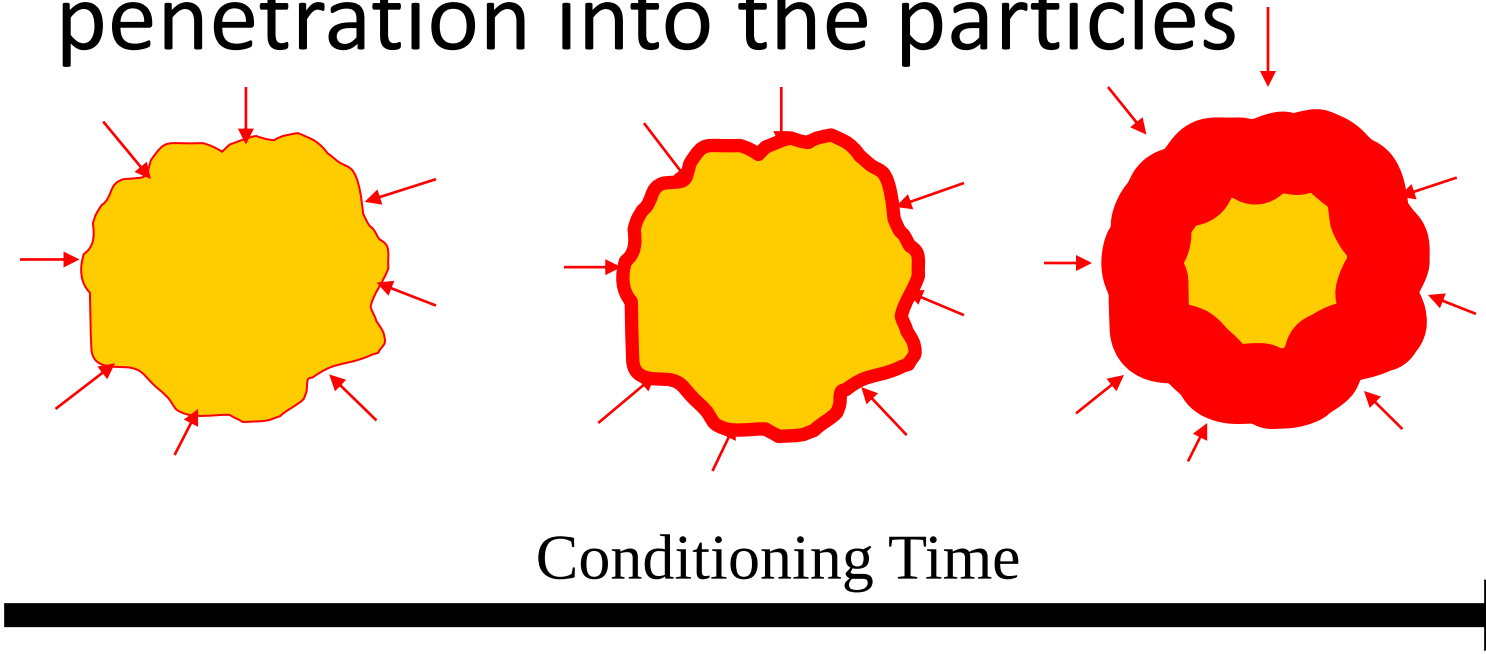
Conditioning Temperature



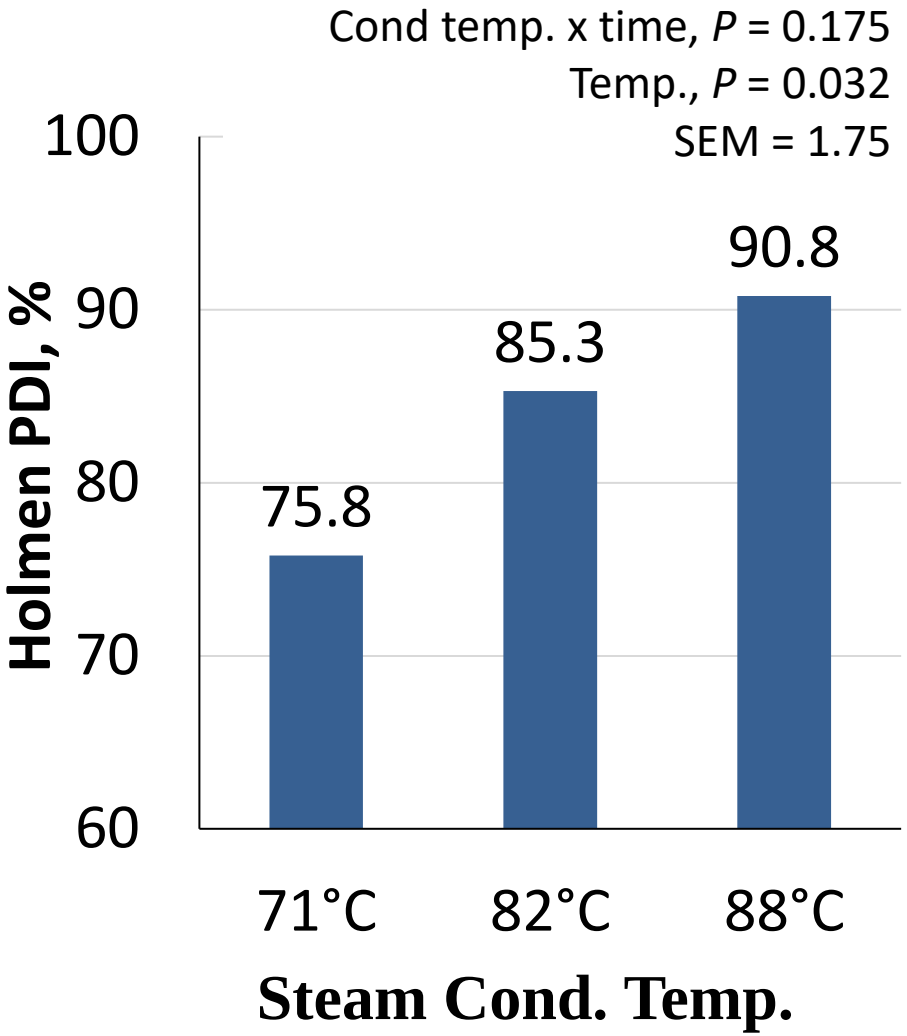
Rueda et al., 2022

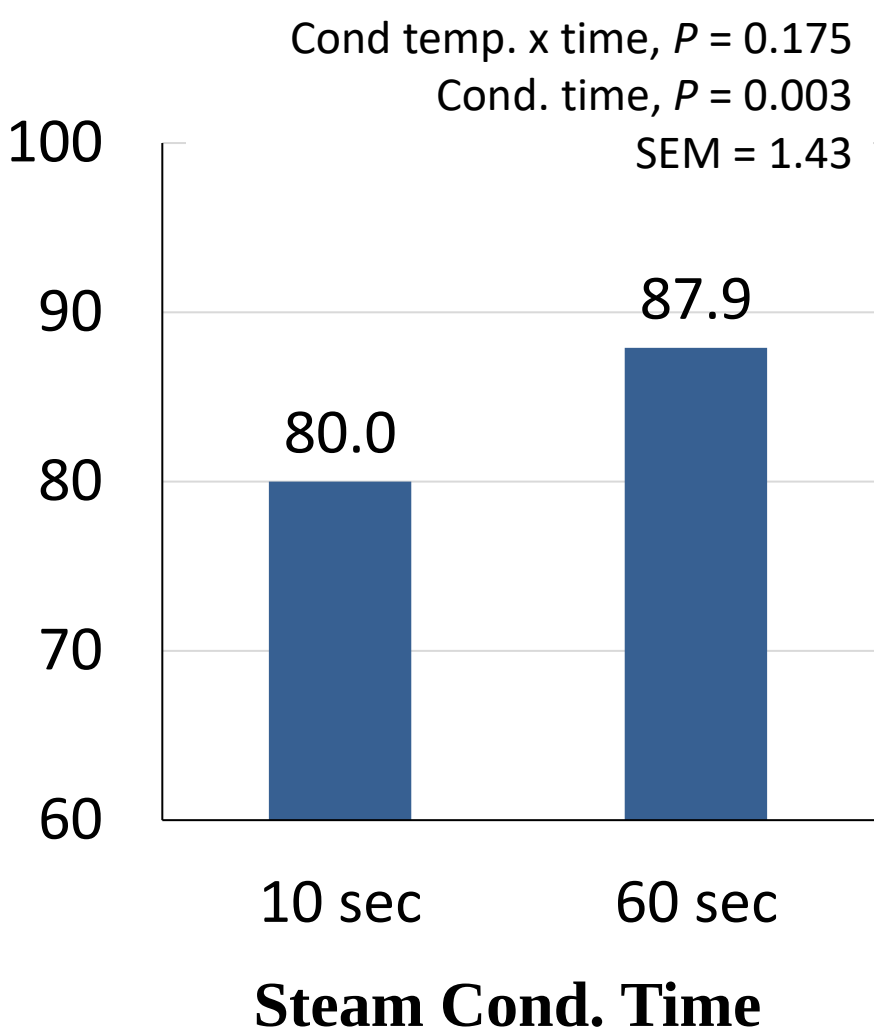
Conditioning Time

- Time
  - Increasing the conditioning time will increase the moisture and heat penetration into the particles



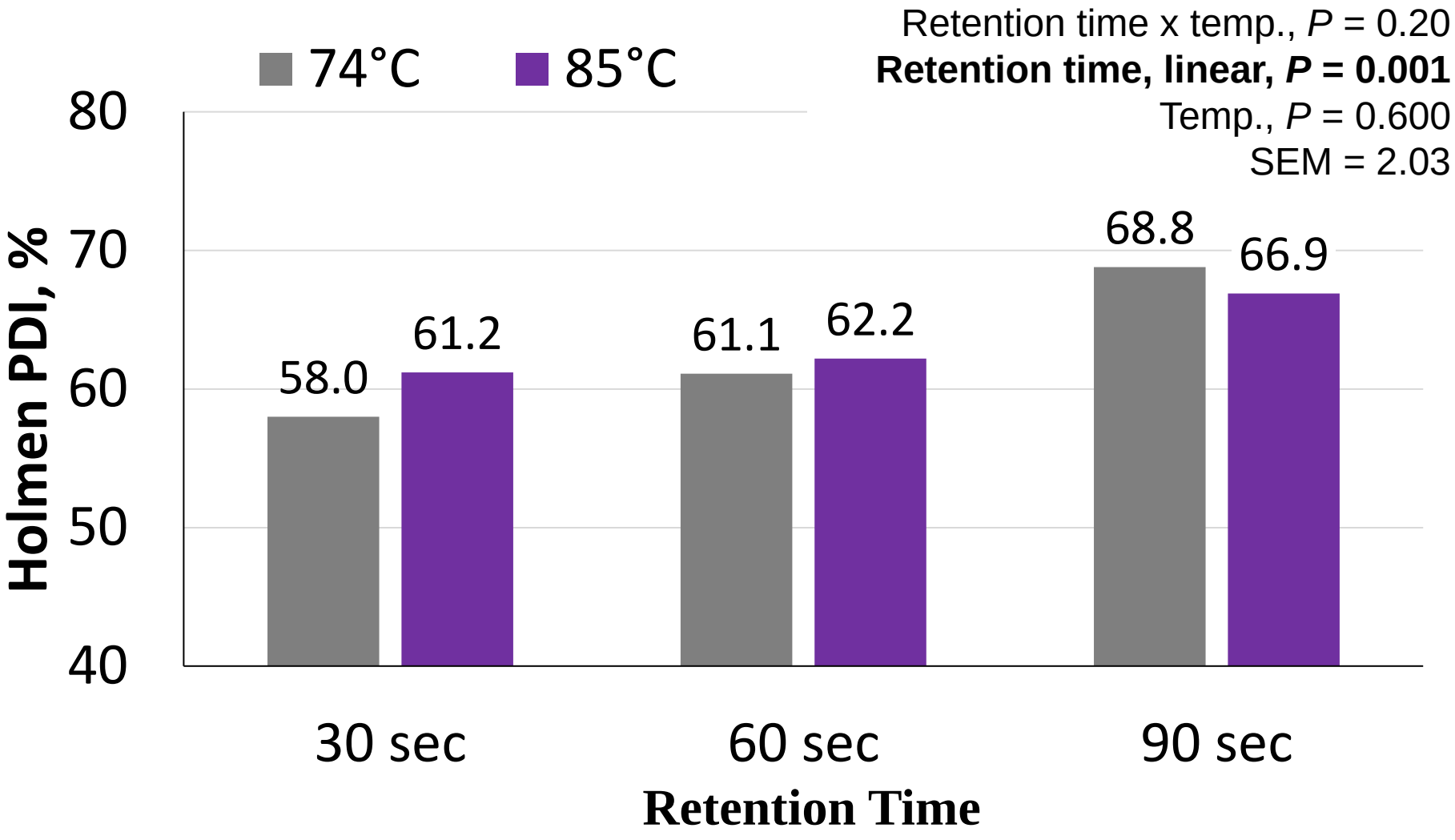
Holmen PDI, %





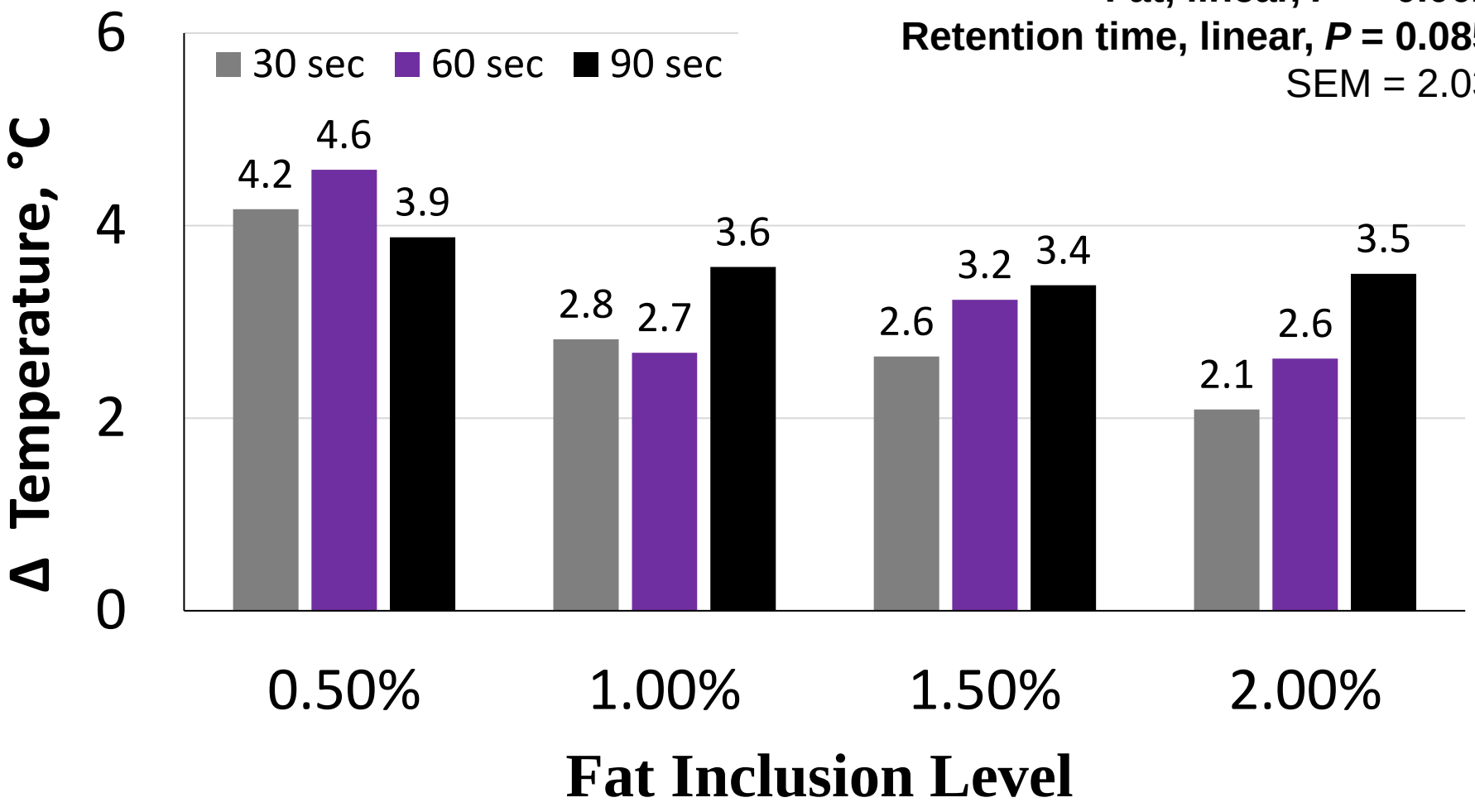
Boney et al., 2018

Holmen PDI, %

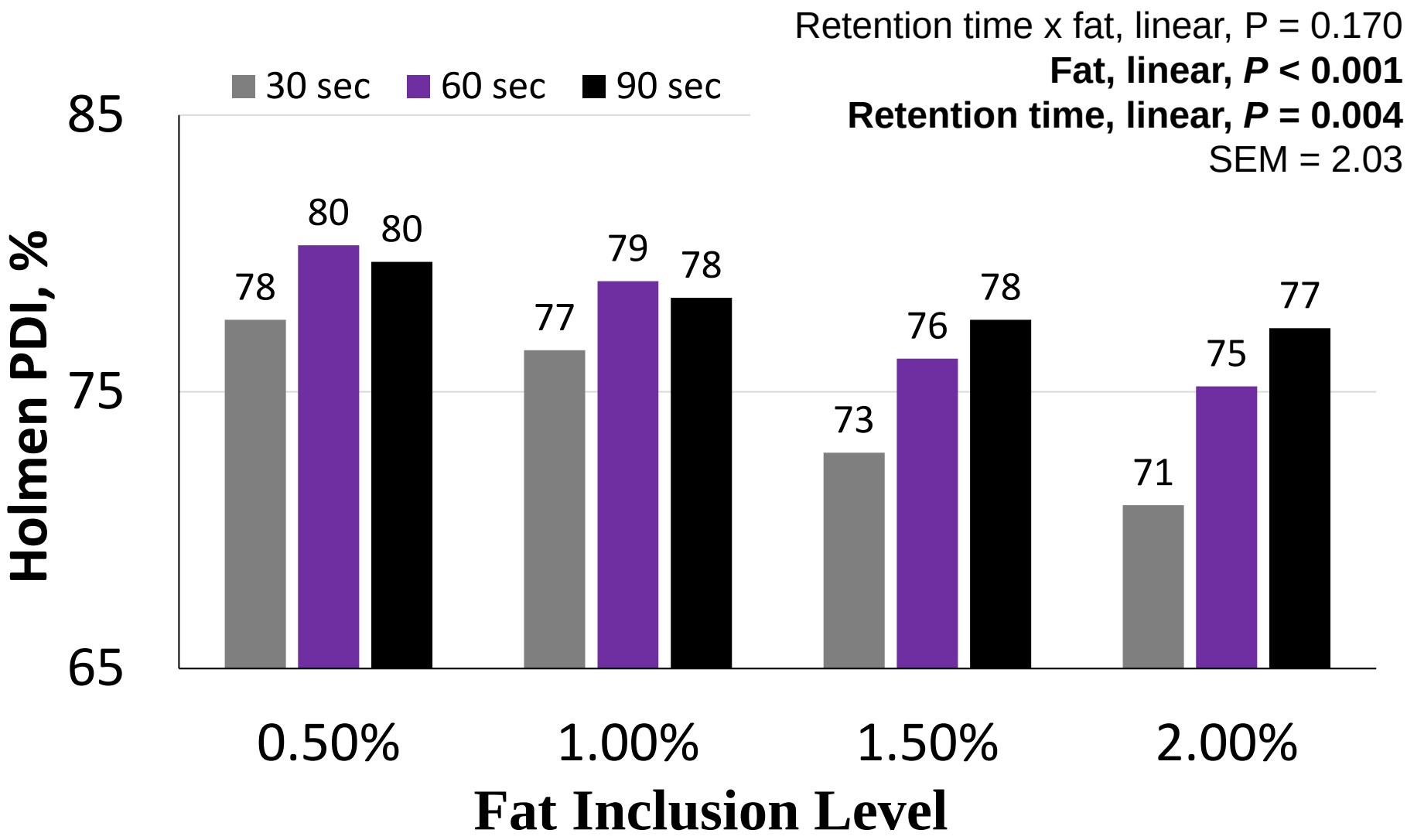

Retention time x temp., P = 0.20
Retention time, linear, P = 0.001
Temp., P = 0.600
SEM = 2.03
74°C
85°C
Holmen PDI, %
80
70
60
50
40
58.0
61.2
61.1
62.2
68.8
66.9
30 sec
60 sec
90 sec
Retention Time

Δ Temperature, °C

Retention time x fat., P = 0.130
Fat, linear, *P* = 0.002
Retention time, linear, *P* = 0.085
SEM = 2.03



Holmen PDI, %


Retention time x fat, linear, P = 0.170
Fat, linear, P < 0.001
Retention time, linear, P = 0.004
SEM = 2.03
30 sec
60 sec
90 sec
Holmen PDI, %
85
75
65
78
80
80
77
79
78
73
76
78
71
75
77
0.50%
1.00%
1.50%
2.00%
Fat Inclusion Level

Broiler Performance and Digestibility

Table 4. Performance of 1- to 25-d-old broilers fed mash or pelleted-crumbled diets submitted to different conditioning times.

	Treatments[1]							
	Mash	P (0)	P (60)	P (80)	P (100)	P (120)	SEM	*P-value*
Feed intake (g)[2]	1269	1312	1351*	1339*	1360*	1362*	0.008	0.0027
Weight gain (g)	962	1027*	1049*	1030*	1071*	1046*	0.008	0.0014
FCR (g/g)	1.320	1.278	1.289	1.302	1.270	1.302	0.005	0.1206

[1]Mash diet (control) and pelleted diets submitted to different conditioning times (0, 60, 80, 100, and 120 s).

[2]Linear effect of conditioning times ($P = 0.04$). $Y = 0.4118x + 1315.2$; $R^2 = 0.859$.

*Indicates difference from the control ($P \leq 0.05$) by Dunnett's test.

Table 5. Coefficients of ileal apparent digestibility (CIAD) of dry matter (DM), starch, and crude protein (CP), and ileal digestible energy content (IDE) determined in 25-d-old broilers fed starter mash (control) or pelleted-crumbled diets submitted to different conditioning times (0, 60, 80, 100, and 120 s).

	Treatments[1]							
	Mash	P (0)	P (60)	P (80)	P (100)	P (120)	SEM	*P-value*
CIAD of DM (%)	57.14	62.90*	65.80*	64.85*	65.59*	66.30*	0.729	<0.0001
CIAD of starch (%)	84.21	84.79	86.32	87.19	85.00	85.65	0.389	0.258
CIAD of CP (%)	71.77	71.53	74.09	74.22*	74.19	76.08*	0.549	0.011
IDE (kcal/kg DM)[2]	2731	2966*	3113*	3094*	3160*	3187*	32.734	<0.0001

[1]Mash diet (control) and pelleted diets submitted to different conditioning times (0, 60, 80, 100, and 120 s).

[2]Quadratic effect of conditioning times ($P = 0.04$). $Y = -0.0036x^2 + 2.2155x + 2969.3$ $R^2 = 0.952$.

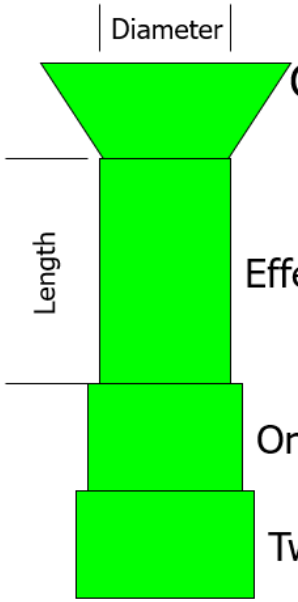
*Indicates difference from the control ($P \leq 0.05$) by Dunnett's test.

Massuquetto et al., et al., 2017

Pellet Mill Die



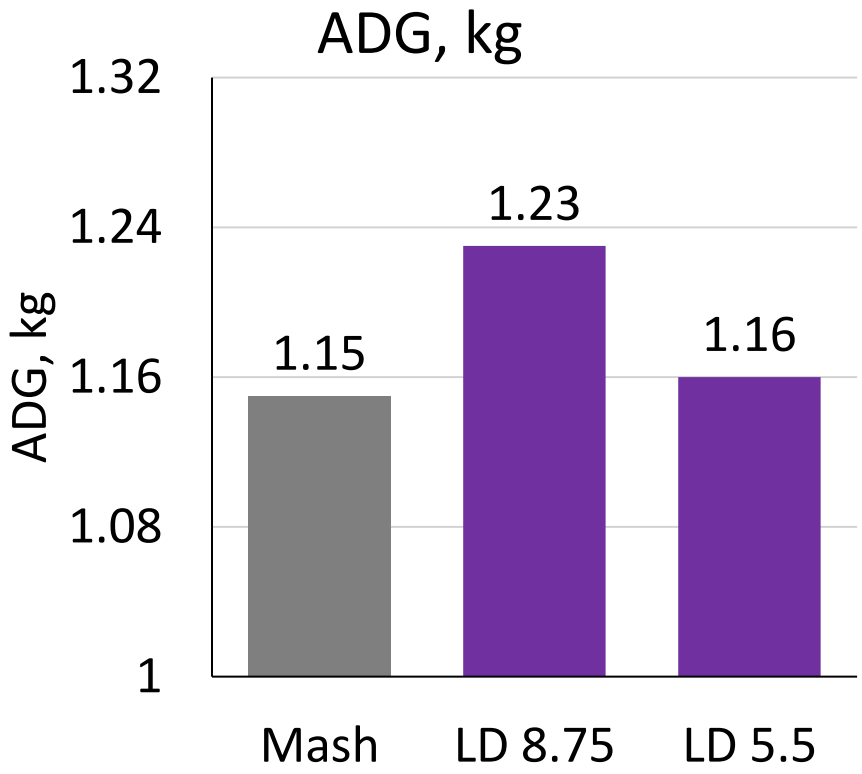
Die Hole Specifications

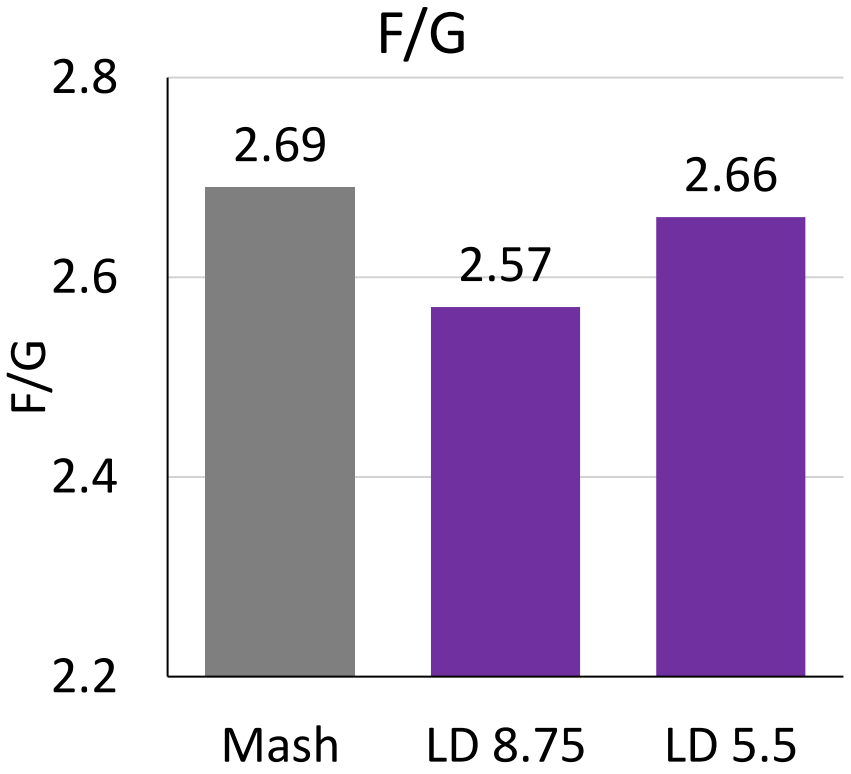


$$L/D = \frac{\text{Length}}{\text{Hole Diameter}}$$

$$\frac{1\text{”}\ ¼\text{”}}{10/64\text{”}} \quad L/D=8$$

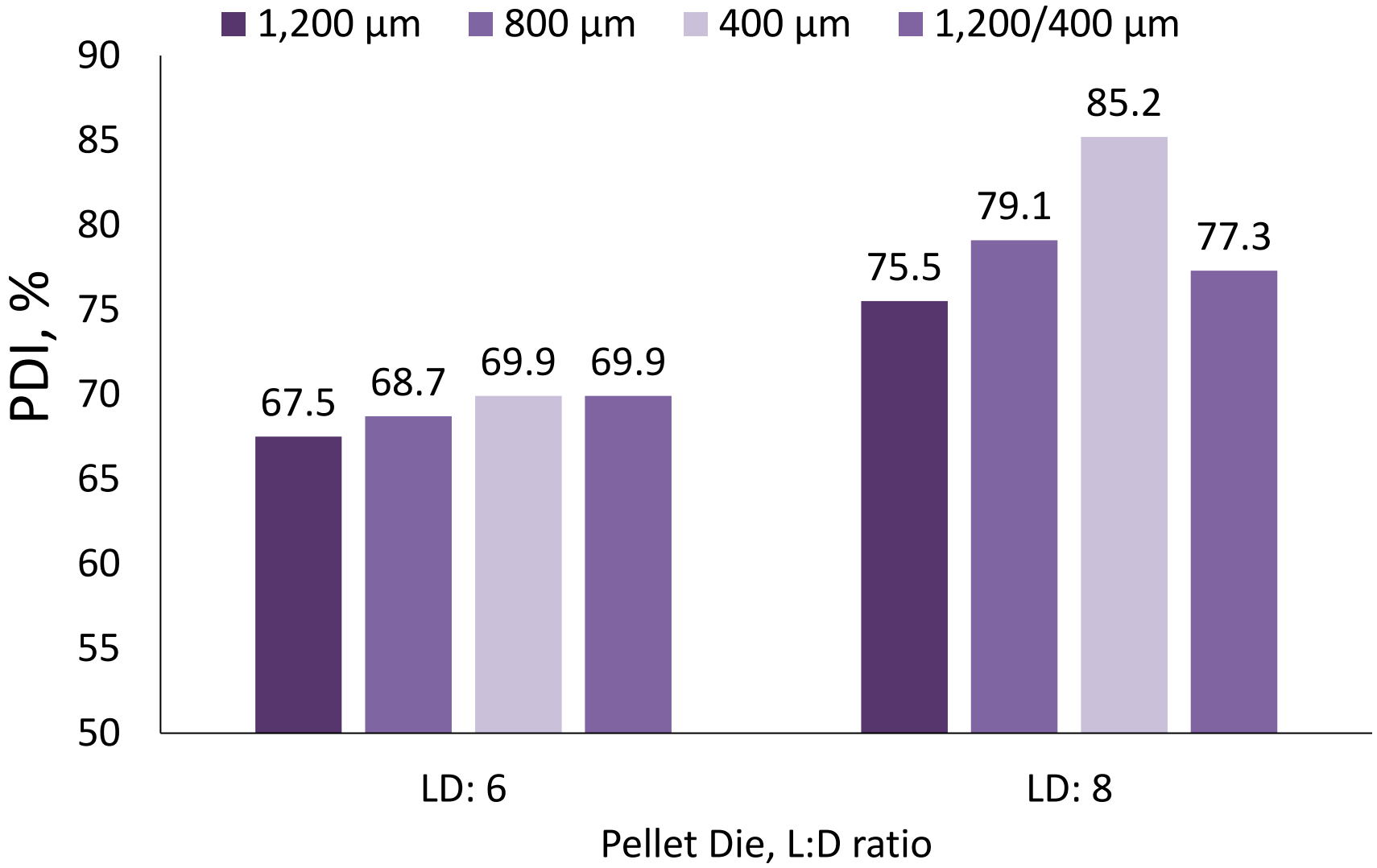
Pellet Die Thickness Example Swine





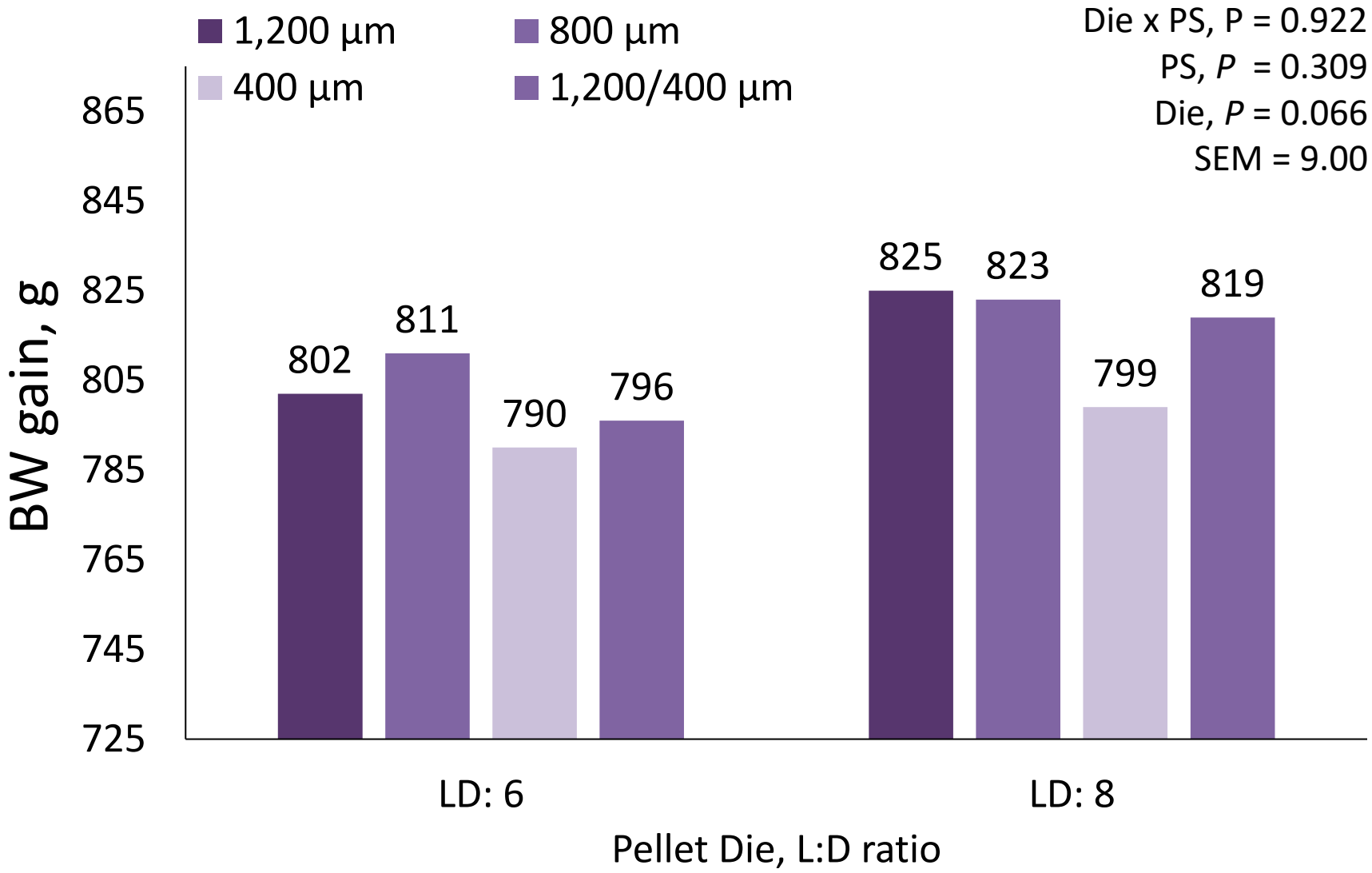
Badger et al., 2023

Particle Size x Die Thickness, Broilers



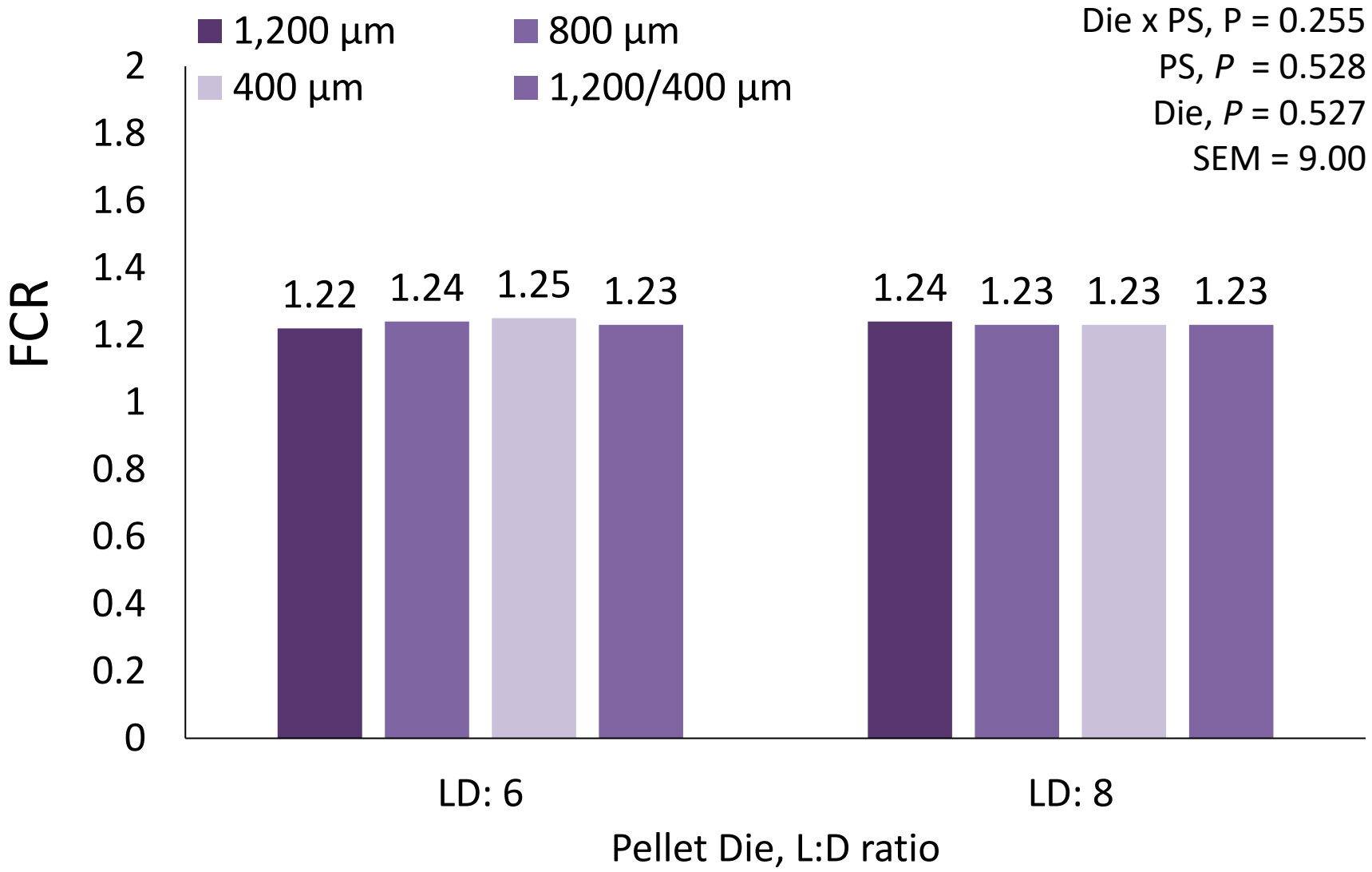
Engnell et al., 2023

Particle Size x Die Thickness, Broilers



Engnell et al., 2023

Particle Size x Die Thickness, Broilers



Engnell et al., 2023

Take Home Message

- How do we optimize the pelleting process to balance the needs of the feed mill and the nutritionist?
- Things we need to understand:
  - Temperature and moisture content
  - Pellet mill die retention time
  - Frictional heat

Quality Feed Manufacturing Guide

Guidelines

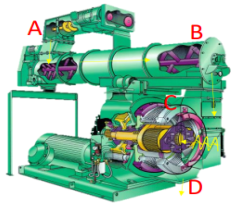
K-STATE Research and Extension | PIC

QUALITY FEED MANUFACTURING GUIDE
GENERAL QUALITY PRINCIPLES

Pelleting

Pelleting swine feed provides many benefits from improved palatability and flowability, to decreased feed wastage, reduced ingredient segregation and destruction of pathogens (Behnke 1994; Figure 1). While pelleting comes at an additional cost of approximately $5 to 6 per ton, the benefits can be realized with improved average daily gain and feed efficiency if pellet quality is maintained. There are numerous factors that impact the pelleting process from diet formulation, pelleting conditions, and specific pellet mill components. Factors that influence percent fines at the feeder include ingredient characteristics, the conditioning process, pellet mill configuration, pellet cooling and transportation.

Figure 1. Feed flow through pellet mill (CPM)
A. Mash feeder
B. Steam conditioner
C. Pellet die
D. Pellet exit to cooler



Monitoring and data collection during the pelleting process

Steam conditioning

Mash feed is steam conditioned prior to forming pellets to increase die lubrication and soften feed particles to increase binding capacity. The process of conditioning is determined by the amount of time feed spends in the conditioner and steam quality. The way in which feed moves from the feeder through conditioner is determined by paddle tip angle and speed. The conditioner should be evaluated weekly by cleaning and examining feed build up more frequently, depending on pelleting tonnage. A continuous flow of feed to the conditioner is important for equal distribution of steam. Monitoring temperature, conditioner retention time, steam quality and conditioned mash moisture throughout the conditioning process will equip mills with the ability to adjust for improvements in pelleted feed quality and pellet mill throughput.

Mash conditioning targets

When conditioning mash feed in preparation for pelleting, some useful targets are 17 to 18% total moisture when mash feed hits the die and 180 to 200°F conditioning temperature for typical corn-soybean meal-based diets. Lower conditioning temperatures are needed to pellet more complex nursery diet formulations but will increase frictional heat, require more energy, decrease throughput, and increase die wear. For example, nursery pig diets with high inclusions of whey included would need to be pelleted at a lower temperature (about 145°F) than a corn-soy finishing pig diet (about 185°F +). Increasing the conditioning temperature will decrease the hot pellet temperature because there is less frictional heat across the die with steam acting as a lubricant.

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Evaluations

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QUALITY FEED MANUFACTURING GUIDE
EVALUATION FORM

Pelleting

Feed Mill Name: _____ Feed Mill Address: _____ Manager: _____
Manager Contact: _____ Evaluator: _____ Date: _____

Instructions
The following is an evaluation of feed quality measures as outlined in the quality feed manufacturing guide. Evaluator should indicate compliance and provide a score of 0 or 1 – where 0 is never compliant and 1 is always compliant. Please provide comments where necessary. Scores will provide indication for areas of improvement providing data to uphold and observe changes in feed quality. Adjustments to total possible points may need to occur if a question is not applicable. Do not answer the question if it is not applicable. Yearly quality assessments are recommended.

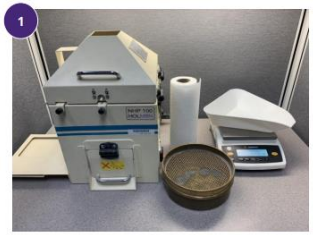
Questions	Score	
Monitoring and data collection during the pelleting process	**1**	**0**
1. Is target conditioning temperature being achieved? Target conditioning temperature: _____ Initial mash moisture: _____	□ Yes	□ No
2. Is target retention time being achieved? Target retention time: _____	□ Yes	□ No
3. Are pellets being cooled equal to or within ±10°F of ambient temperature?	□ Yes	□ No
4. ***Is there even feed bed depth in pellet cooler?**	□ Yes	□ No
5. Are pellet fines being cleaned from cooler?	□ Yes	□ No
6. Is PPLA system being verified with bucket tests? Date of last bucket test: _____ If no PPLA, select "yes"	□ Yes	□ No
7. Is there less than 1% fat being added to the mixer?	□ Yes	□ No
Comments		
Equipment monitoring		
8. Is tonnage per die being recorded? Current tons/die: _____	□ Yes	□ No
9. Are the pellet dies evenly worn?	□ Yes	□ No
10. Are the die rolls evenly worn?	□ Yes	□ No
Comments		
Testing pellet quality		
11. Is pellet durability method defined? Method used: _____	□ Yes	□ No
12. Is method being followed? What modifications?	□ Yes	□ No
13. Is PDI determined according to schedule?	□ Yes	□ No
14. ***Is target PDI being achieved?**	□ Yes	□ No
15. Is there documentation about customer complaints for pellet quality? If no complaints, select "yes"	□ Yes	□ No
Comments	**Total: ___/15**	

Visual reminders

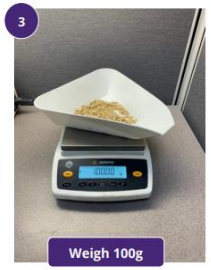
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QUALITY FEED MANUFACTURING GUIDE
VISUAL REMINDERS

HOLMEN NHP100 SERIES









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https://www.grains.k-state.edu/research/index.html

Feed Science Research Team





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