Impact of feeding biofuels co-products on pork fat quality

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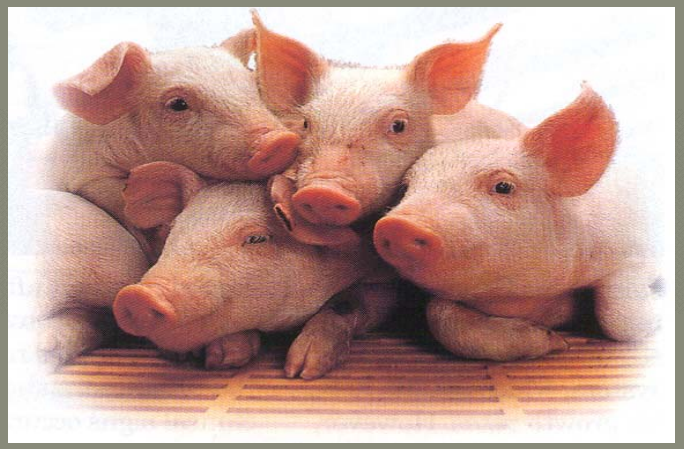
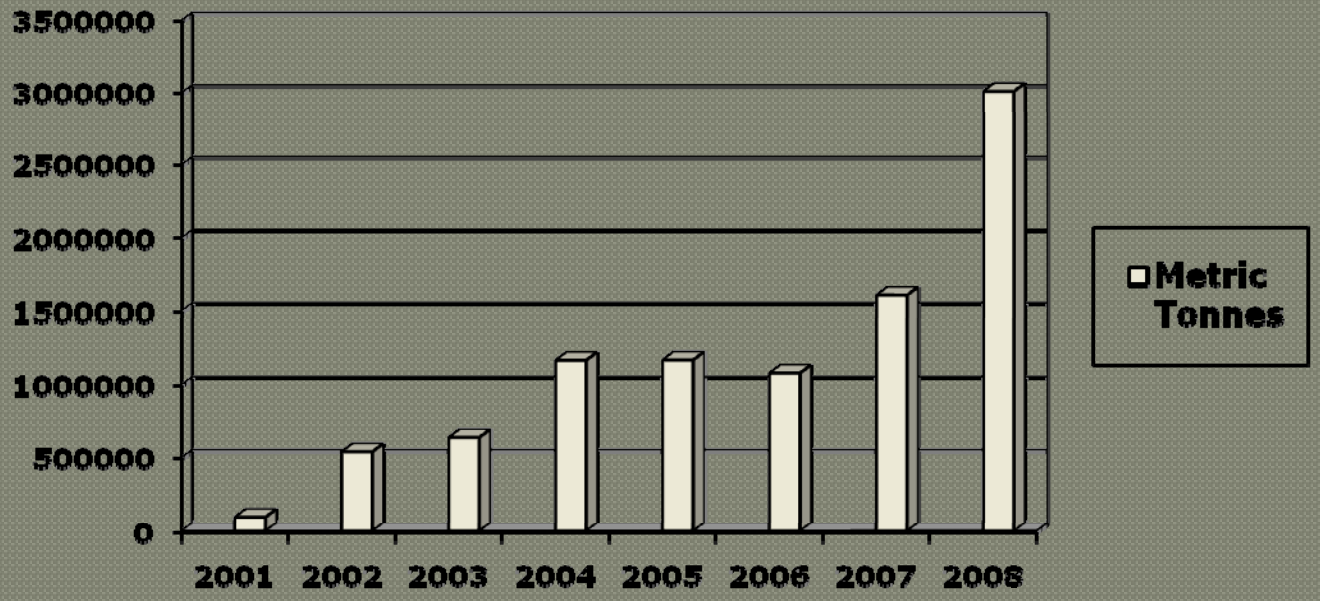
Introduction

- "Pigs are what they eat"



- Diet fatty acid (FA) composition affects FA profile in pork fat
- FA composition varies among adipose tissue sites
  - IV of backfat > belly fat and jowl fat > loin fat
- Dietary FA composition has a greater impact on:
  - High lean genotypes (low backfat)
  - Gilts

Estimated use of DDGS in U.S. swine diets (2001-2008)



What is different about feeding grower-finisher pigs today?

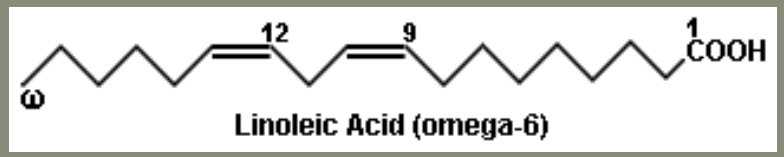
- DDGS (~ 10% corn oil)
  - ~ 3 - 4 million MT is consumed in U.S. pork industry
    - ~85% is used in G-F diets
      - Fed at levels up to 40% of the diet
      - Has resulted in $3 to $6/market hog feed cost savings

- Reduced oil corn co-products
  - Becoming more available
  - Limited information about feeding value
  - Less concerns about pork fat quality but energy content is reduced

What is the main concern?

- The dietary level and feeding duration of unsaturated fatty acids

- Linoleic acid (C18:2)

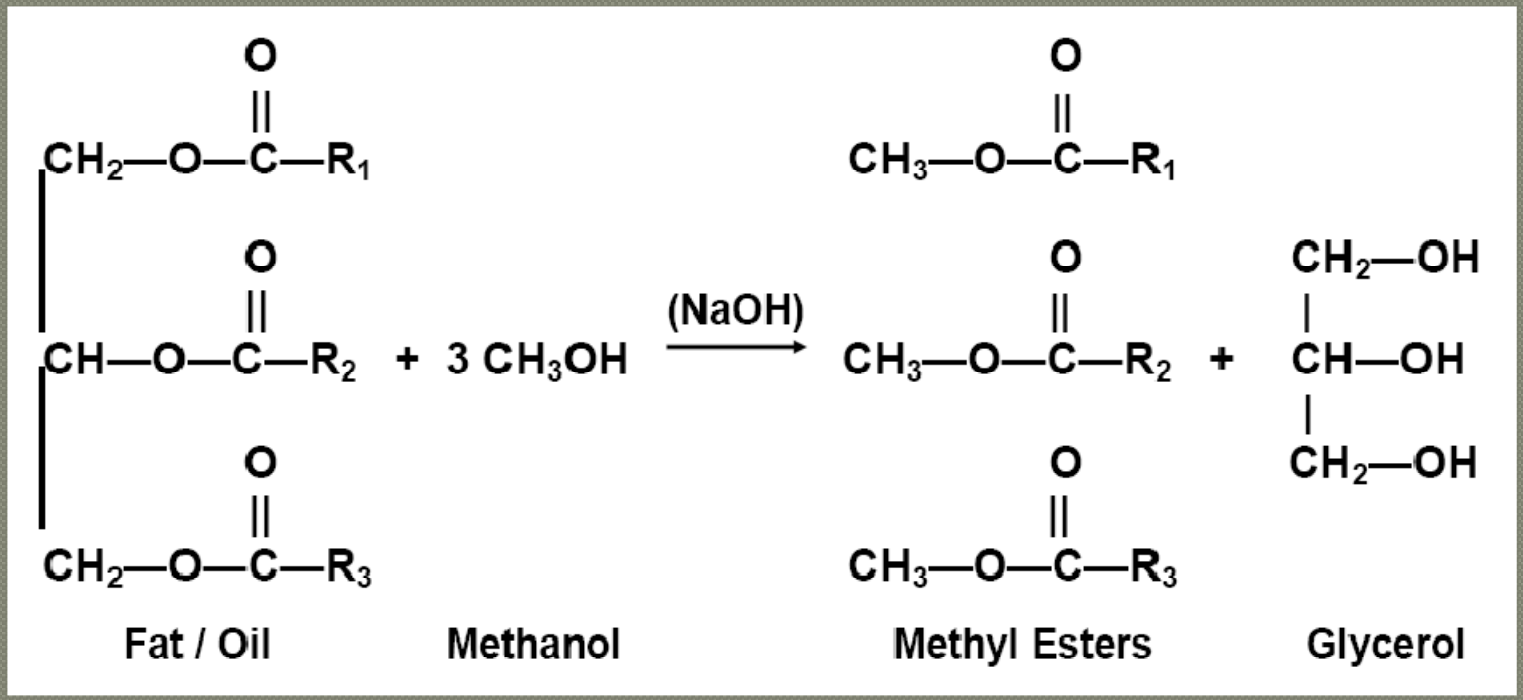


  - Represents ~ 60% of fatty acids in corn oil
  - Reduces the omega 6:omega 3 ratio in pork fat
  - May contribute to reduced shelf life of fresh pork
  - May cause metabolic oxidation imbalance
  - May increase the need for vitamin E or other dietary antioxidants

Other emerging biofuels co-products

- Crude glycerol may become more available depending on:
  - Sustainability of the biodiesel industry
  - Economics relative to other dietary energy sources
  - Availability of supply
  - Methanol content (< 150 ppm)
- Growing interest in feeding liquid co-products from the ethanol industry
  - Steep water (wet milling)
  - Condensed distillers solubles (dry grind)

Crude glycerol is a by-product of biodiesel production

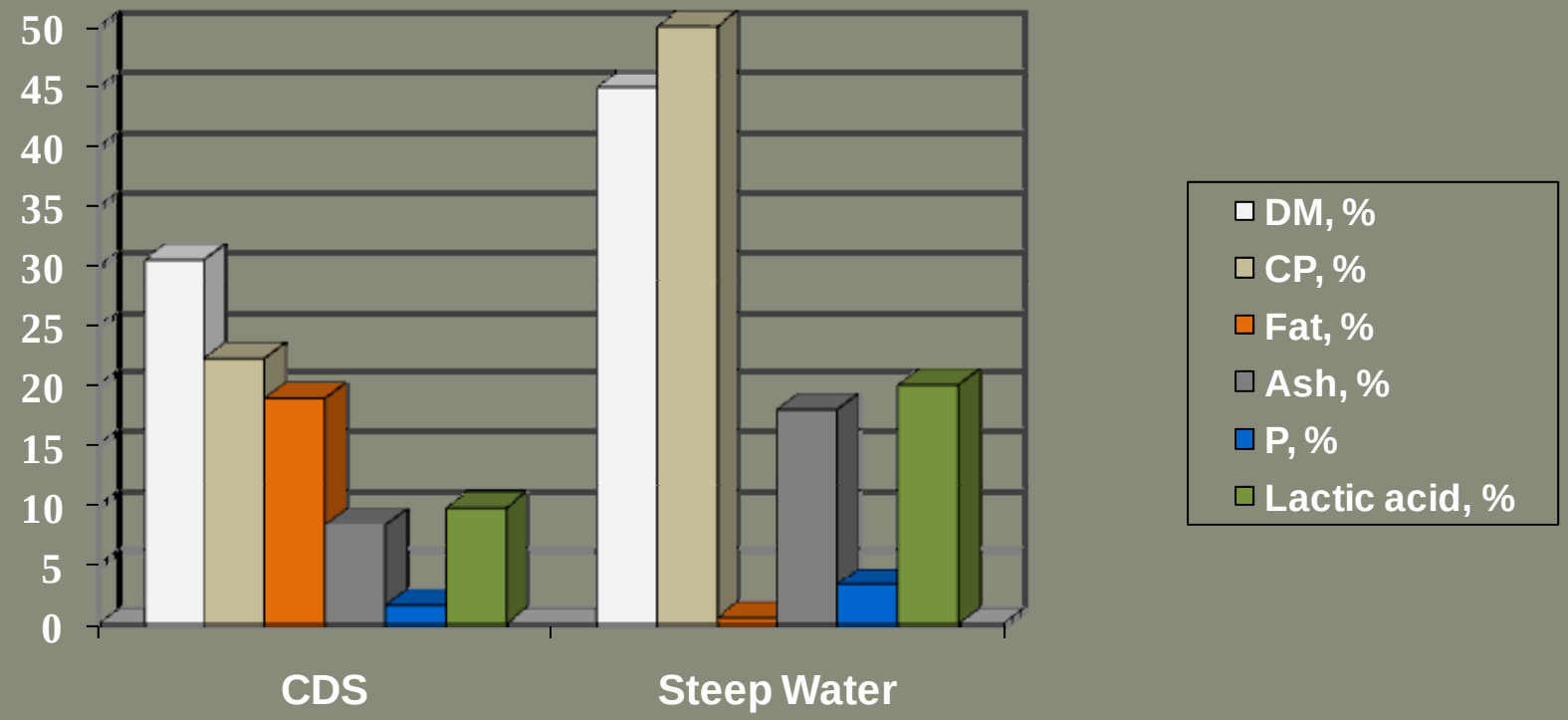


Nutrient composition of biofuels co-products (DM basis)

Co-Product	ME, kcal/kg	Crude fat, %	ADF, %	NDF,%	Lysine, %
DDGS[1]	3,414 - 4,141	10.2 - 12.1	8.6 - 14.4	33.4 - 49.1	1.0 - 1.3
RO-DDGS[1]	3,650	3.2	15.8	51.0	1.0
Dried CDS[1]	**4,525**	**11.8**	**0.50**	**2.3**	1.1
DH-DG Corn[1]	4,316	**0.2**	**0.50**	4.3	**0.2**
Germ meal[1]	3,417	2.4	12.5	**61.1**	1.2
HP-DDG[1]	3,676 – 4,606	2.9 – 7.0	12.6 – **25.4**	32.0 – 51.1	1.2 – **1.6**
LS – DDG[2]	**2,959**	8.8	20.4	-	1.0
Glycerol[3]	3,207	-	-	-	-

Corn ME (kcal/kg) = 3,843 (NRC, 1998)
[1]Data from Anderson et al. (2009)
[2]Data from Amaral et al. (2009)
[3]Data from Lammers et al. (2008)

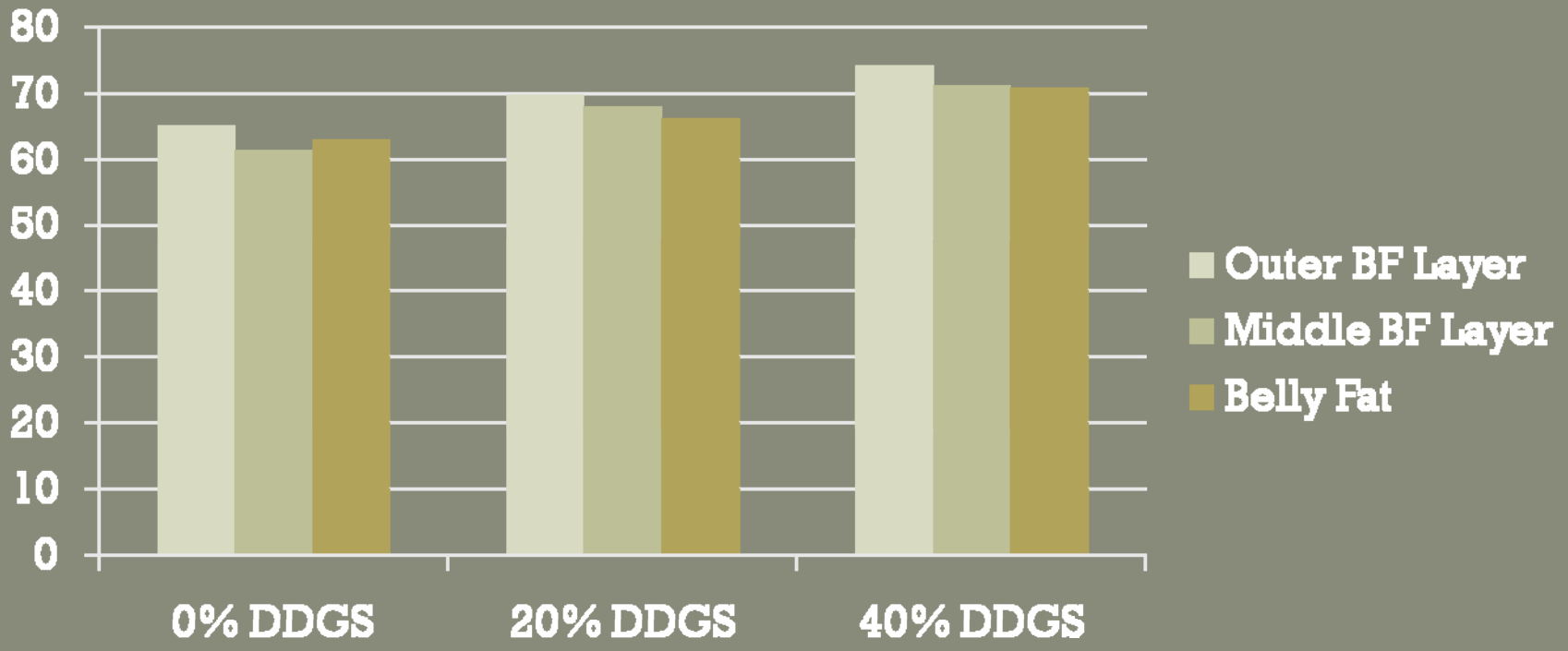
Nutrient content of corn condensed solubles and corn steep water (DM basis)



Current Pork Fat Quality Standards

- Not well defined and questionable
  - Based on Iodine Value (IV)
    - ratio of unsaturated:saturated fatty acids
- Suggested maximum IV
  - 70 – Danish Meat Research Institute
  - 70 – National Pork Producers Council
  - 74 – Boyd et al. (1997)
- Various adipose tissue sites are affected differently by dietary fatty acid composition

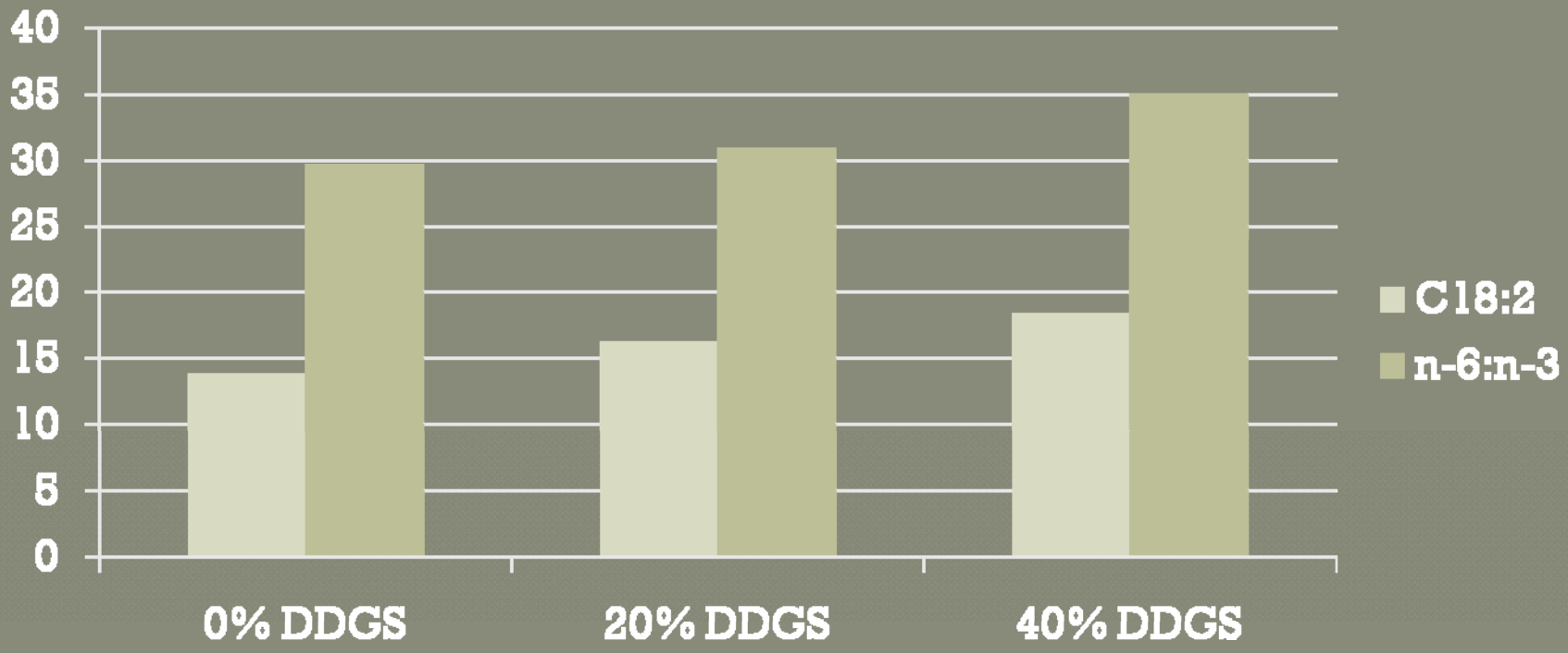
Effects of Feeding Grower-Finisher Diets Containing DDGS on IV of Backfat and Belly Fat



Fat depot location main effect ($P < 0.05$)
DDGS main effect ($P < 0.05$)
DDGS linear effect ($P < 0.05$)

White et al., 2009

Effects of feeding 0, 20, and 40% DDGS diets on C18:2 and n-6:n-3 ratio in belly fat

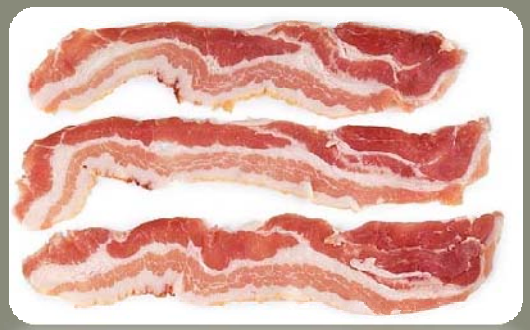


DDGS main effect ($P < 0.05$)
DDGS linear effect ($P < 0.05$)

White et al., 2009

Questions

- What should the standards be for U.S. pork fat quality?
- Is IV the best criteria?
  - If the answer is yes…
    - How do you measure it on a commercial harvest/processing facility?
    - How is IV measured and/or calculated?
    - What adipose tissue depot should be used?
    - What is the maximum IV for acceptable pork fat quality?
  - If the answer is no, what criteria do you use?
    - Belly firmness?
      - Durometer?
    - Subjective appearance? (at what temperature?)
    - Others?



What is the impact from feeding DDGS to grower-finisher pigs?

Summary of growth performance responses from feeding levels up to 30% DDGS to grower-finisher pigs

Performance Measure	N	Increased	Reduced	Not Changed
ADG	25	1	6	18
ADFI	23	2	6	15
Gain/Feed	25	4	5	16

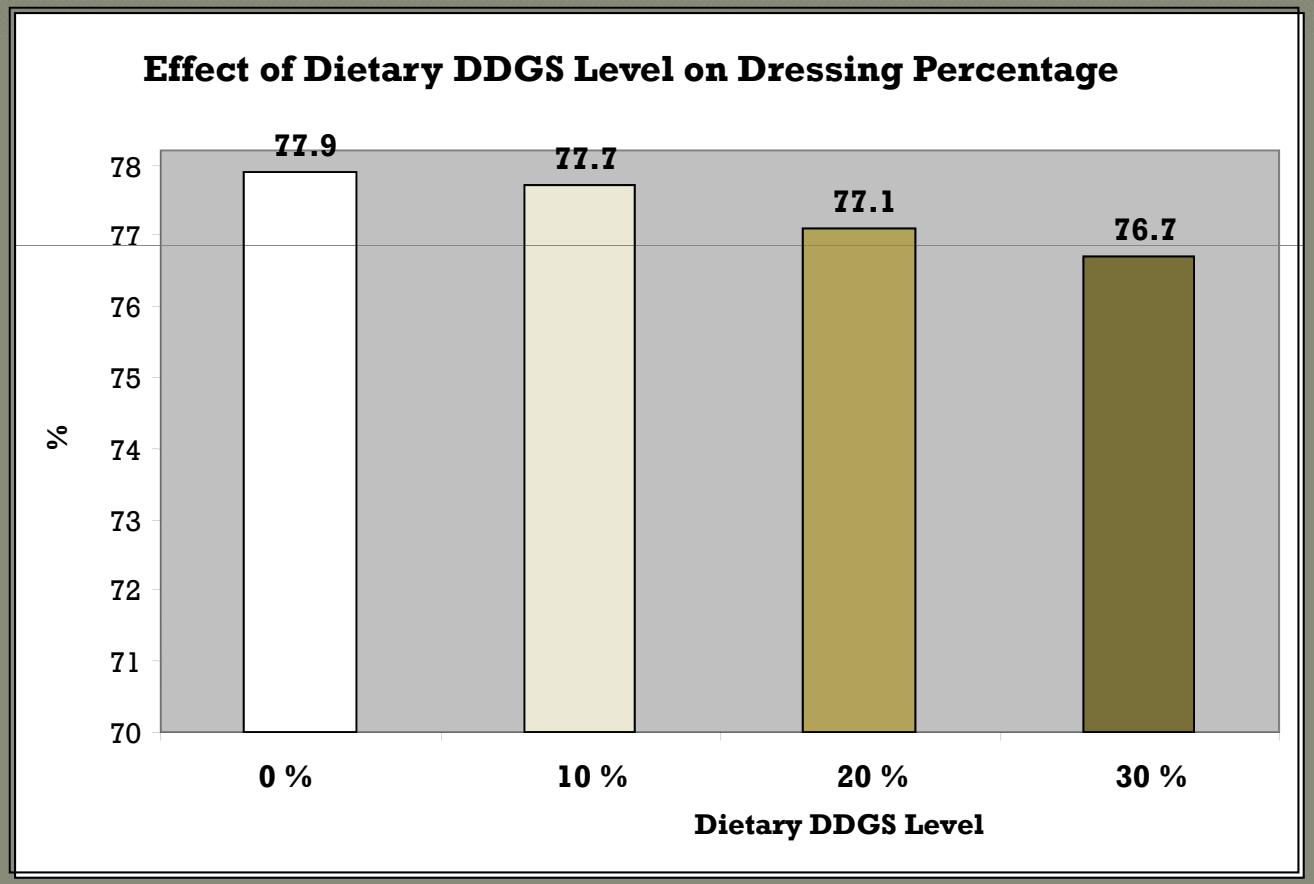
Stein and Shurson, 2009

Summary of carcass characteristic responses from feeding levels up to 30% DDGS to grower-finisher pigs

Performance Measure	N	Increased	Reduced	Not Changed
Dressing %	18	0	8	10
Backfat thickness	15	0	1	14
Loin depth	14	0	2	12
% Carcass lean	14	0	1	13

Stein and Shurson, 2009

Increasing Dietary Levels of DDGS MAY Reduce Carcass Dressing Percentage



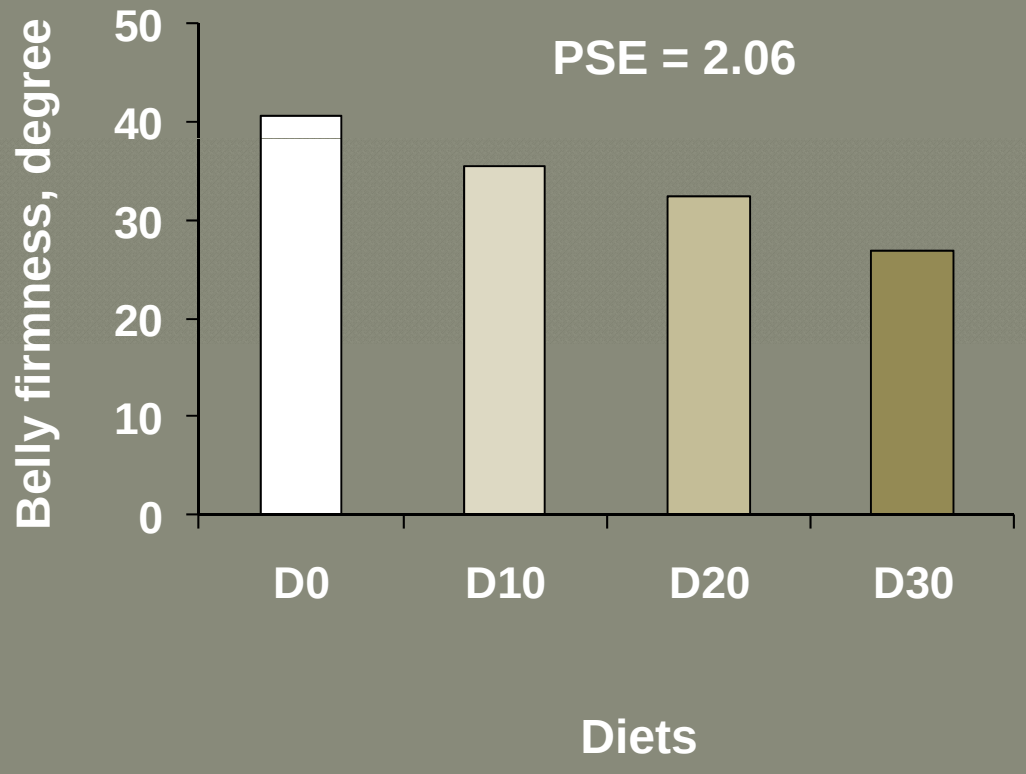
Xu et al. (2009)
Linear effect ($P < 0.01$)

Summary of belly quality characteristics from feeding levels up to 30% DDGS to grower-finisher pigs

Performance Measure	N	Increased	Reduced	Not Changed
Belly thickness	4	0	2	2
Belly firmness	3	0	3	0
Iodine value	8	7	0	1

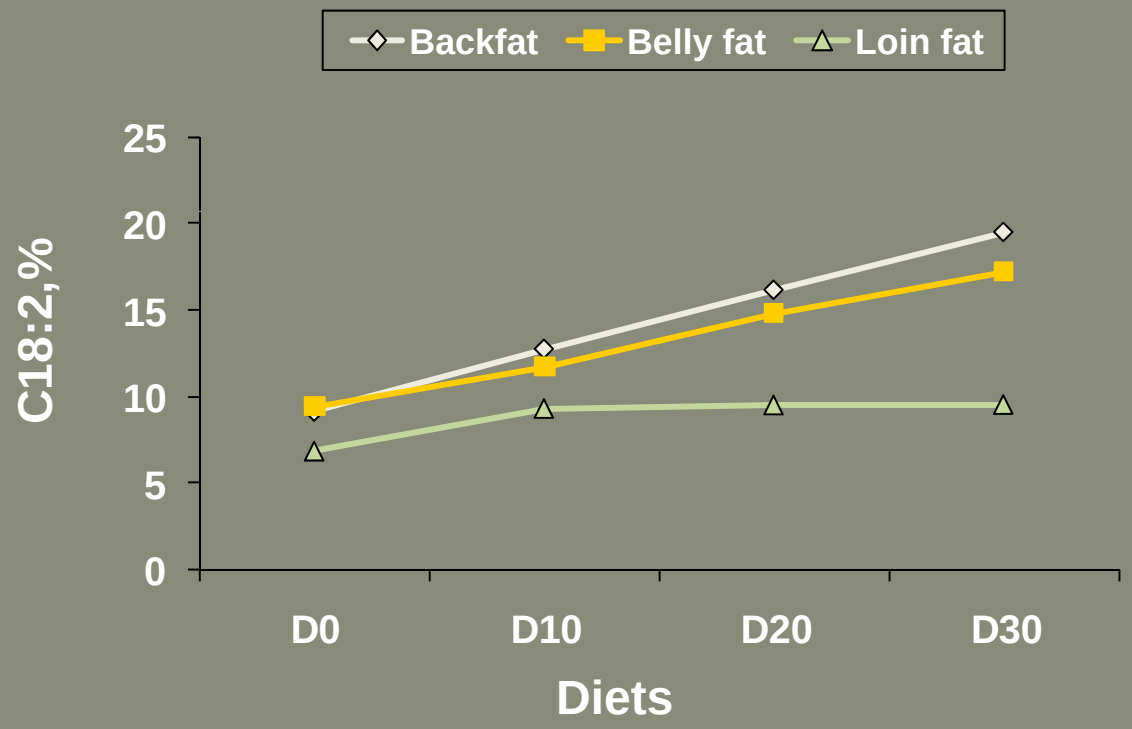
Stein and Shurson, 2009

Effects of feeding 0, 10, 20, and 30% DDGS diets on belly firmness (Xu et al., 2009)



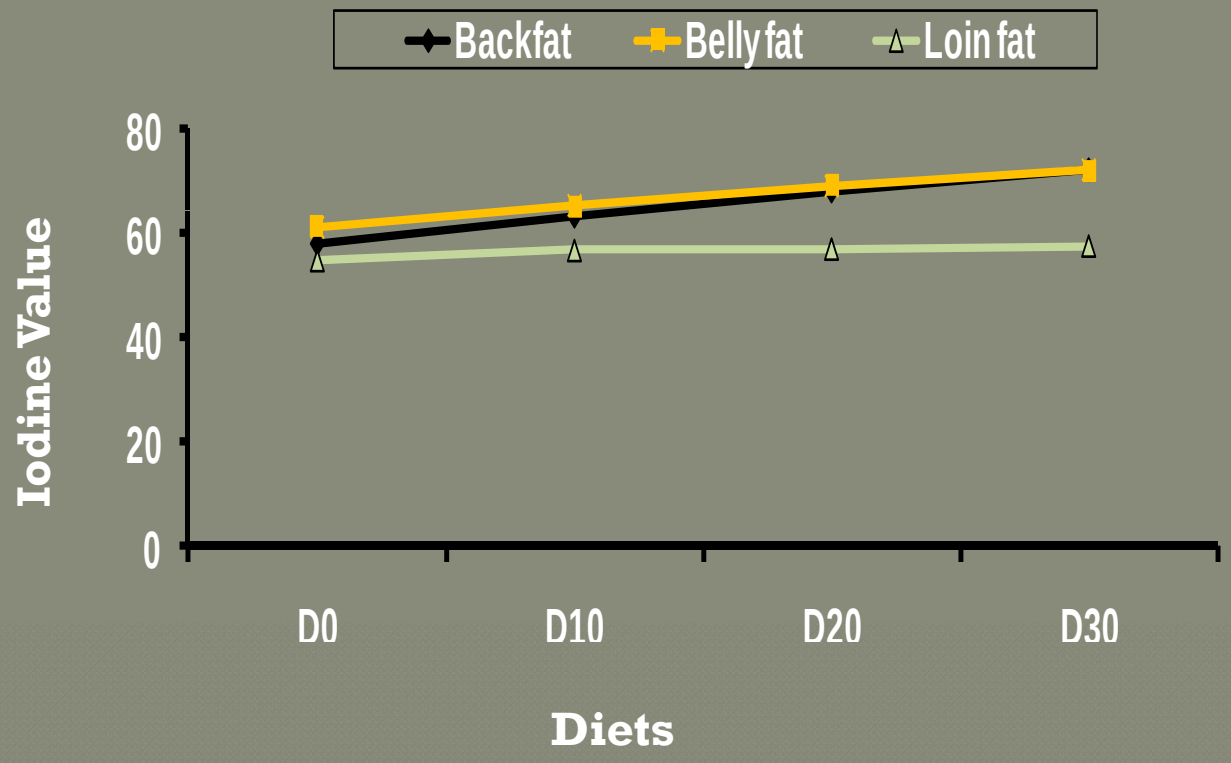
D10 vs. D0 (P > 0.05)
D20 < D0 (P < 0.05)
D30 < D0 (P < 0.05)

Effects of feeding 0, 10, 20, and 30% DDGS diets on C18:2 content of pork fat (Xu et al., 2009)



Linear effect of DDGS for all fat depot sites (P < 0.01)
Diet × site (P < 0.01)

Effects of feeding 0, 10, 20, and 30% DDGS grower-finisher diets on iodine value of pork fat (Xu et al., 2009)



Linear effect of DDGS level for all fat depot sites ($P < 0.01$)
Diet × site ($P < 0.01$)

Effects of feeding 0, 10, 20, and 30% DDGS diets on fatty acid content of pork fat (Xu et al., 2009)

- Linear increase
  - PUFA
  - IV
    - Backfat (58, 63, 68, 72)
    - Belly fat (61, 65, 69, 72)
    - Loin fat (52, 57, 57, 58)
- Linear decrease
  - monounsaturated fatty acids
  - saturated fatty acids

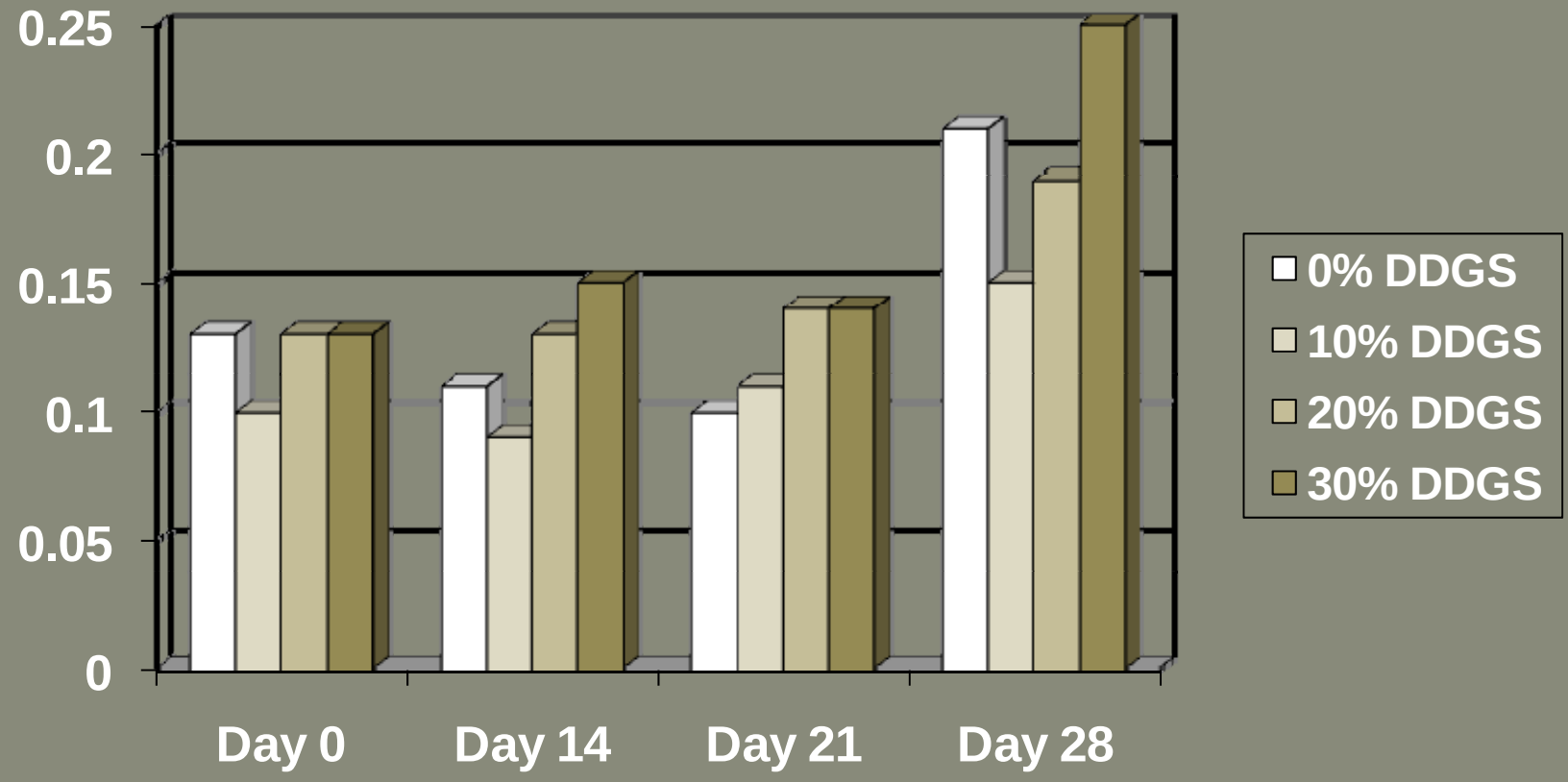
Effects of feeding 0, 10, 20, and 30% DDGS diets on belly and backfat characteristics (Xu et al., 2009)

- No differences in:
  - belly thickness
  - belly fat color
    - Japanese color score
    - Minolta L*, a*, b*
  - backfat color
    - Japanese color score
    - Minolta a*, b* (lower L* for pigs fed the 20% and 30% DDGS diets)

Effects of feeding 0, 10, 20, and 30% DDGS grower-finisher diets on loin characteristics (Xu et al., 2009)

- **No difference in:**
  - ultimate pH
  - subjective color score
  - drip loss on day 0, 14, 21, or 28 post-harvest
  - lipid oxidation in loins at 28 days of shelf storage
- Linear reduction in
  - firmness
  - marbling
  - Minolta a* and b*
  - **But ALL within current accepted NPPC quality standards**

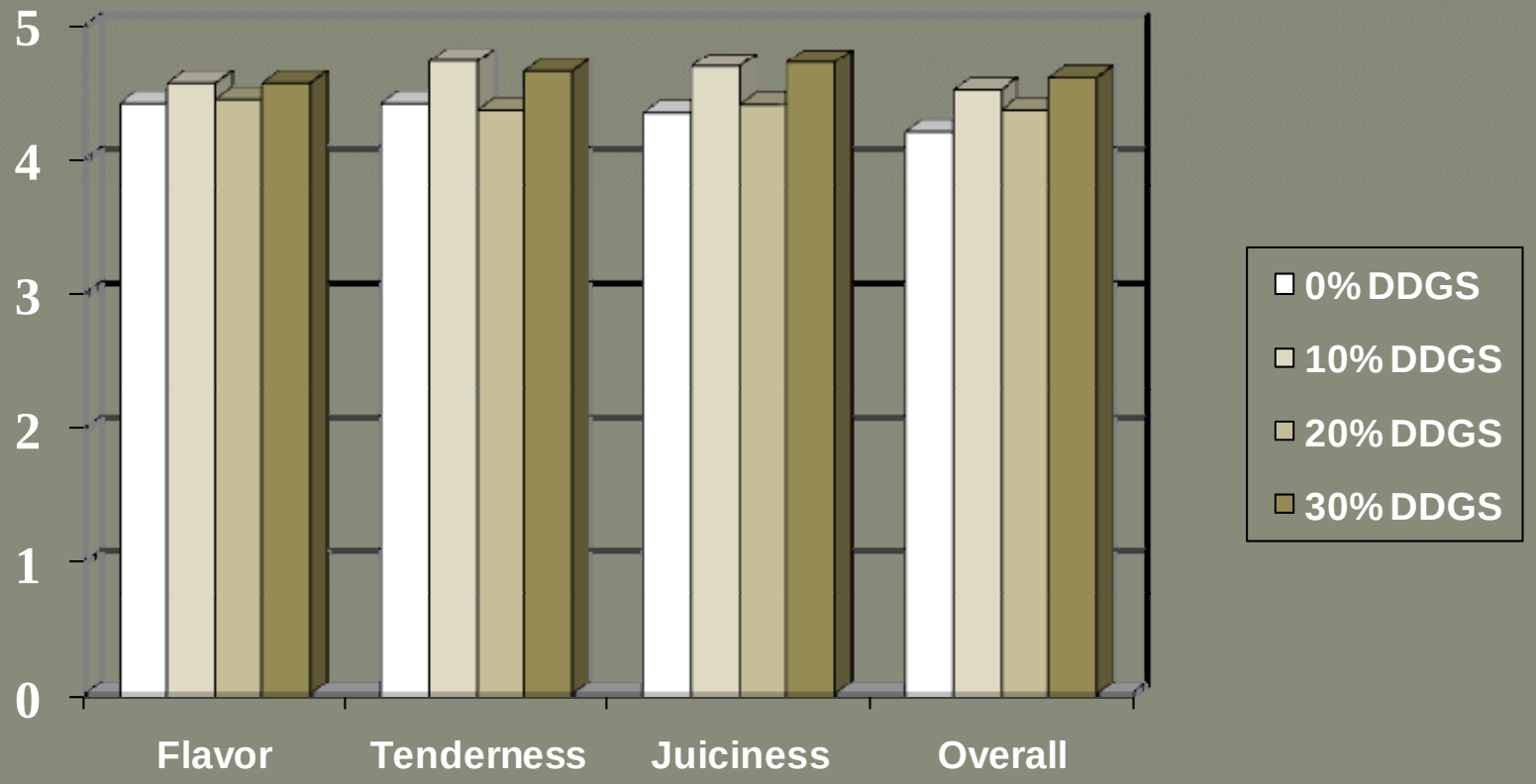
Effects of feeding 0, 10, 20, and 30% DDGS diets on fat stability of pork loins (TBARS, mg malonaldehyde/kg) (Xu et al., 2009)



No significant differences among dietary treatments.

Effects of feeding 0, 10, 20, and 30% DDGS diets on sensory characteristics of cooked pork loins

(Xu et al., 2009)



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Effects of feeding 0, 10, 20, and 30% DDGS diets on sensory characteristics of cooked pork loins

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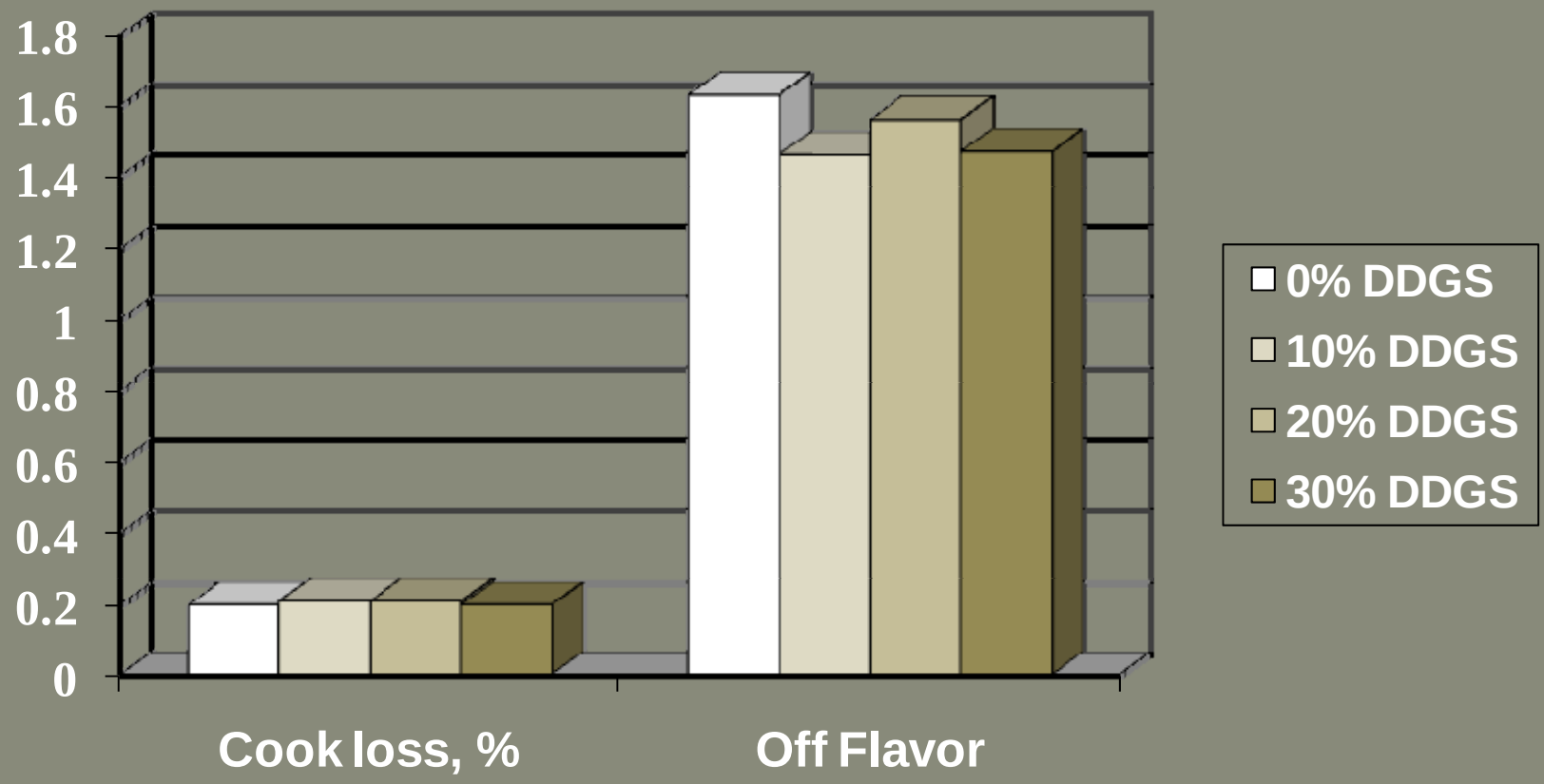
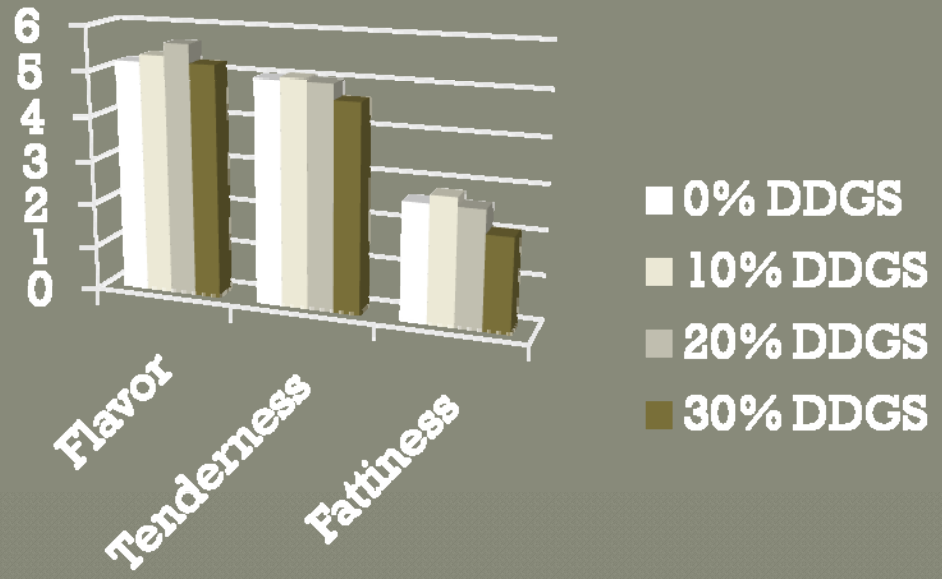


No significant differences among dietary treatments.

Effects of feeding 0, 10, 20, and 30% DDGS diets on sensory characteristics of cooked bacon

(Xu et al., 2009)

- No differences in:
  - Cooking yield
  - Crispiness
  - Off-flavor
  - Overall acceptability



Quadratic effect for flavor ($P < 0.05$)
Linear effect for tenderness ($P < 0.05$)
Linear and quadratic effect for fattiness ($P < 0.01$)

Flavor: high = intense
Tenderness: high = tough
Fattiness: high = fatty

The Positives

- Feeding diets containing up to 30% DDGS has **no adverse** effects on:
  - growth performance
  - carcass backfat thickness
  - % carcass lean
  - belly thickness
  - backfat and belly fat color
  - loin muscle characteristics (met current NPPC target values)
  - loin fat oxidation
  - loin sensory characteristics
  - bacon sensory characteristics

The Negatives

- Yield was linearly reduced (77.9 to 76.7%)
- Belly firmness was linearly reduced
- Bacon appears "greasy" (30% DDGS)
- PUFA content and IV of pork fat were linearly increased
  - highest IV = 72 (30% DDGS)
  - > current NPPC standard of 70
  - < 74 (IV threshold suggested by Boyd et al., 1997)

- Depending on pork fat quality standards used, maximum usage rate of DDGS in grower-finisher swine diet can be 30%.

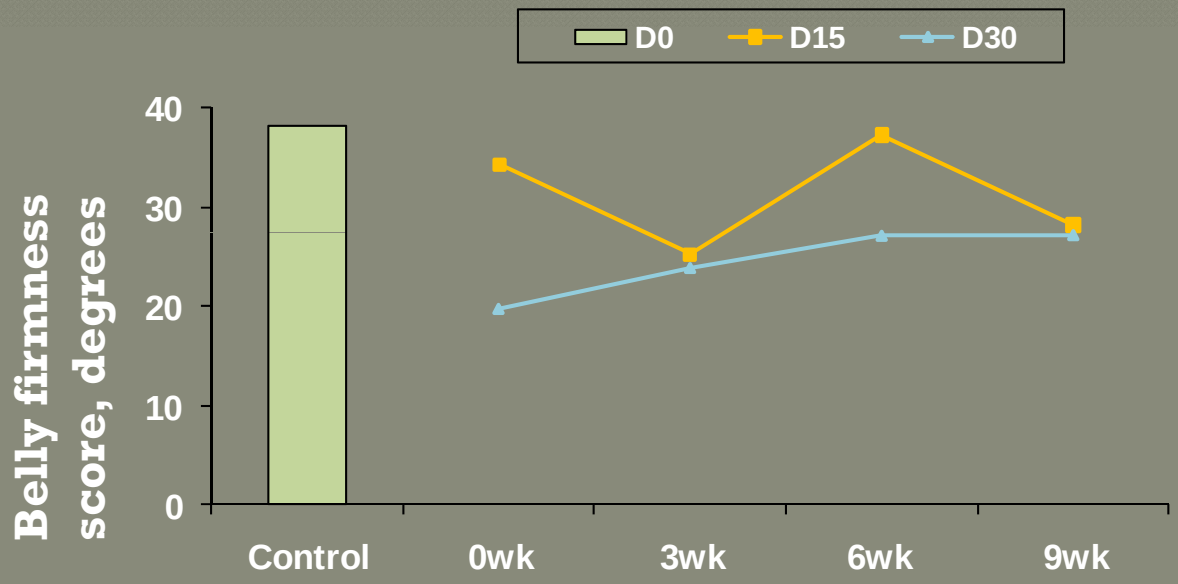
Diet formulation and feeding strategies to improve pork fat quality

- Withdrawing DDGS from the diet before harvest?
- Impact of feeding wheat and barley based diets?
- Feeding reduced corn oil co-products
- Adding conjugated linoleic acid?
- Formulate diets based on iodine product value?
- Add crude glycerol to DDGS diets?
- Add saturated supplemental fat sources (e.g. tallow) to DDGS diets?

Effect of feeding 15 or 30% DDGS diets and withdrawing DDGS from the diet 0, 3, 6, and 9 weeks pre-harvest

- Belly firmness
  - D30-0 < control
- Belly fatty acid composition
  - PUFA
    - Increased with DDGS level
    - Decreased with DDGS withdrawal
      - Control = D15-9
  - Iodine value
    - Increased with DDGS level
    - Decreased with DDGS withdrawal
      - Control = D15-9 and D30-9
  - Monounsaturated fatty acids
    - Increased with DDGS level
  - Saturated fatty acids
    - Decreased with DDGS level
    - Increased with DDGS withdrawal

Effect of dietary DDGS level and withdrawal interval on belly firmness



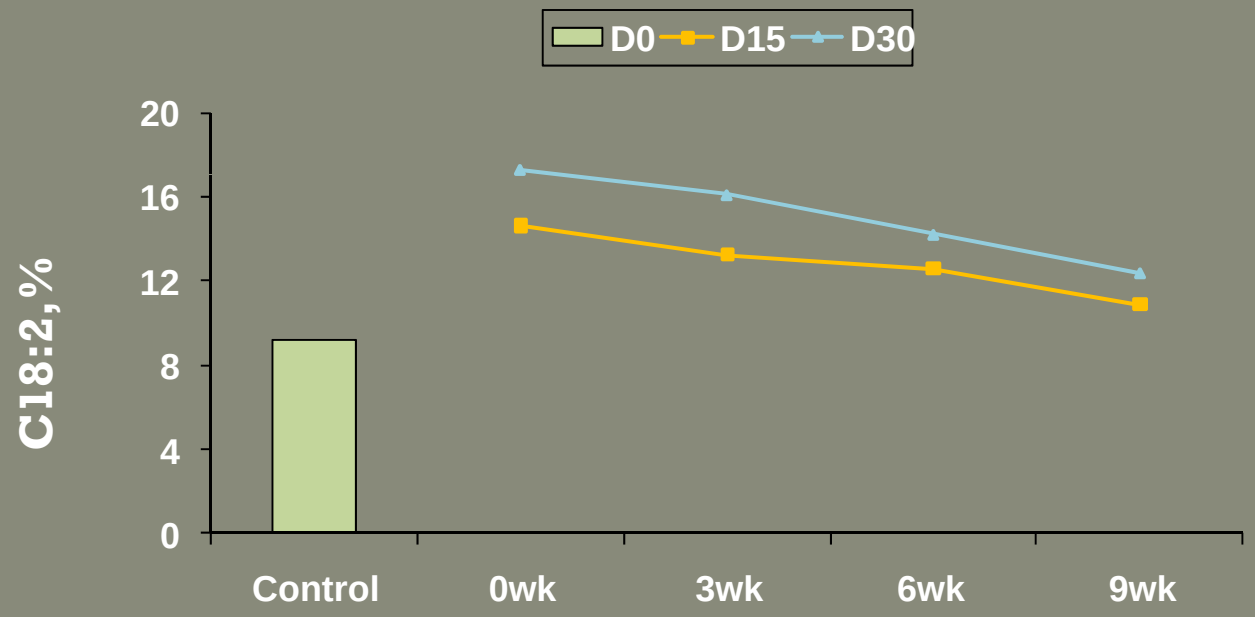
PSE = 1.19

P-value
D = 0.99
W = 0.53
D × W = 0.20

DDGS withdrawal interval

D30-0 < control (P < 0.05)

Effect of dietary DDGS level and withdrawal interval on C18:2 content of belly fat



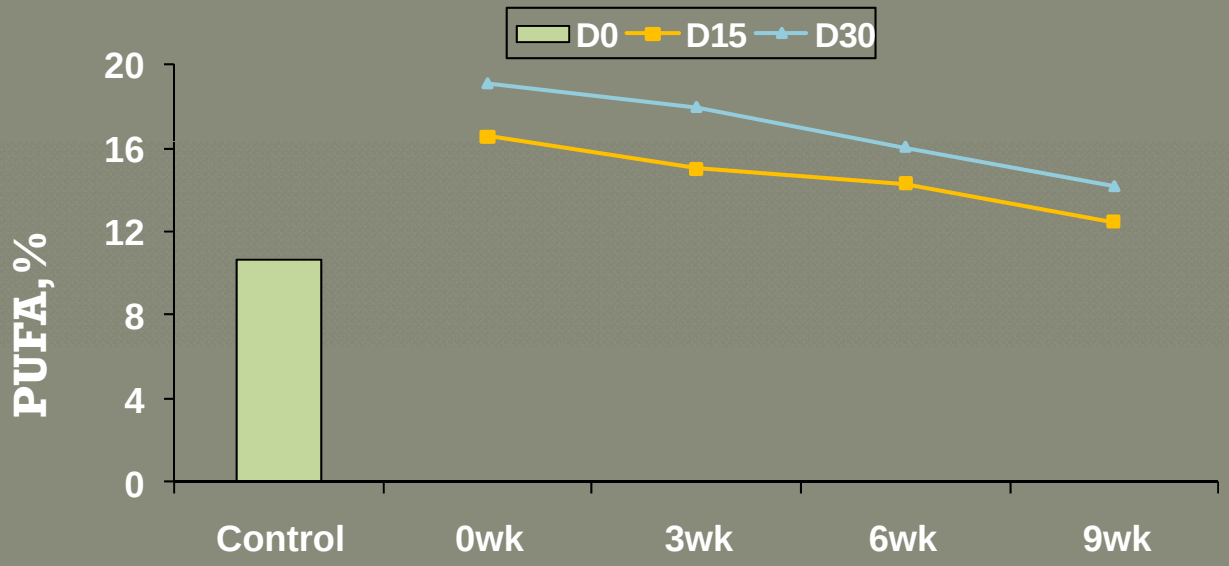
PSE = 0.67

P-value
D < 0.001
W < 0.001
D × W = 0.67

DDGS withdrawal interval

All treatments > control (P < 0.05)

Effect of dietary DDGS level and withdrawal interval on PUFA of belly fat



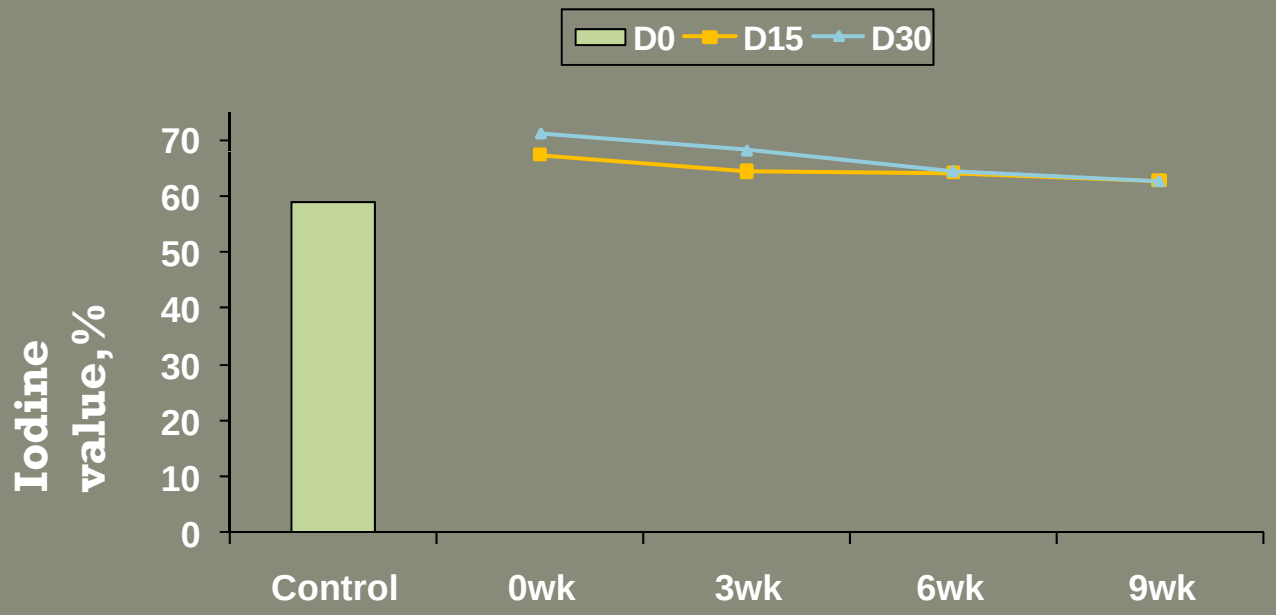
PSE = 0.74

P-value
D < 0.001
W < 0.001
D × W = 0.8

DDGS withdrawal interval

D15-9 wk = control, others > control ($P < 0.01$)

Effect of dietary DDGS level and withdrawal interval on IV of belly fat



PSE = 1.30

P-value
D < 0.001
W < 0.001
D × W = 0.3

D15-9 wk and D30-9 wk = control

All others > control ($P < 0.05$)

Summary of the effects of DDGS withdrawal interval pre-harvest

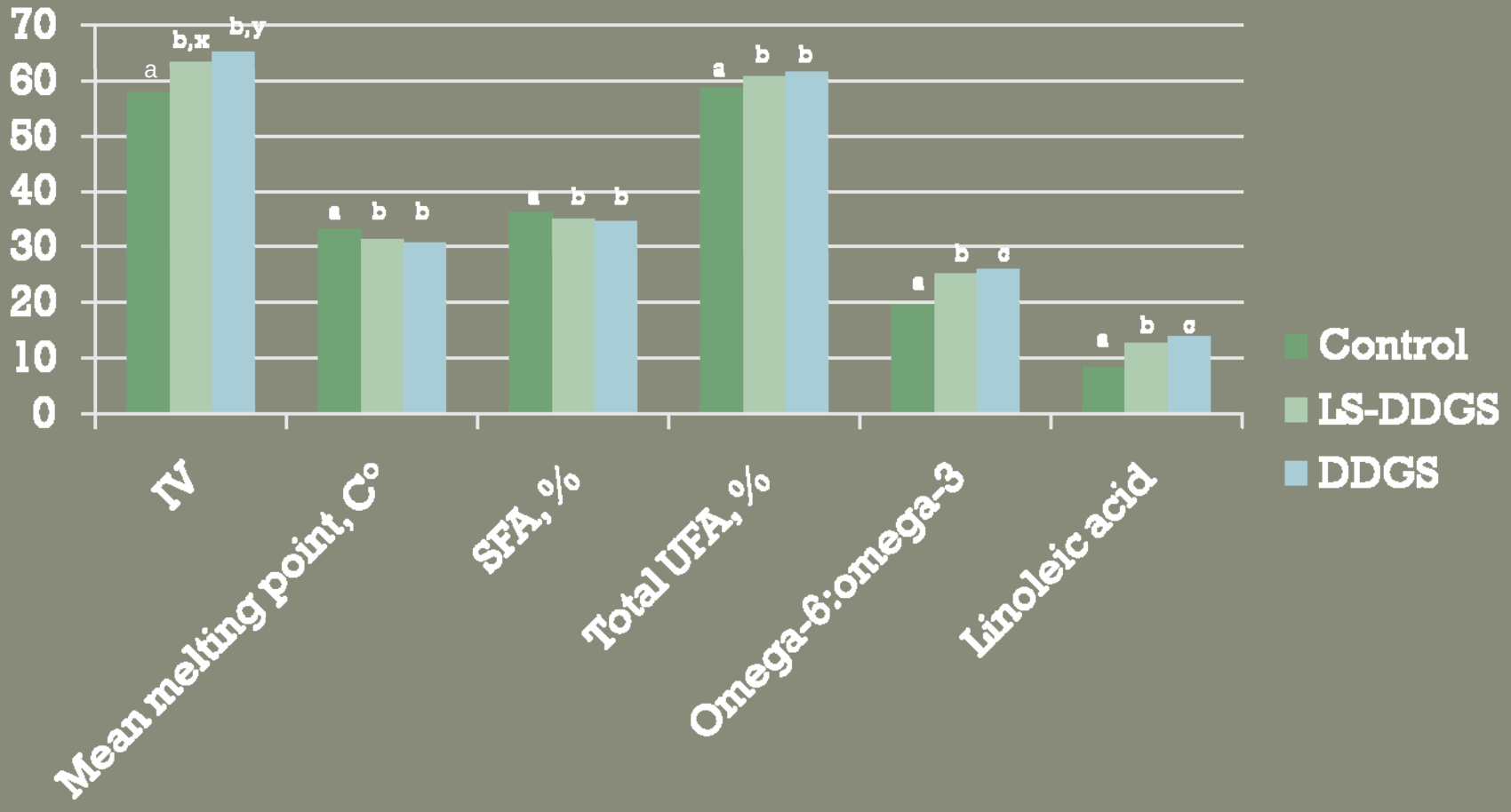
- C18:2 and IV of belly fat are linearly reduced over time when DDGS is removed or reduced in the diet

- IV $\leq$ 70 can be achieved under the following feeding scenarios:
  - 15% dietary DDGS throughout the G-F period with no withdrawal
  - 30% dietary DDGS with a 3 wk withdrawal interval pre-harvest

Effects of feeding reduced oil and high oil corn co-products on pork fat quality

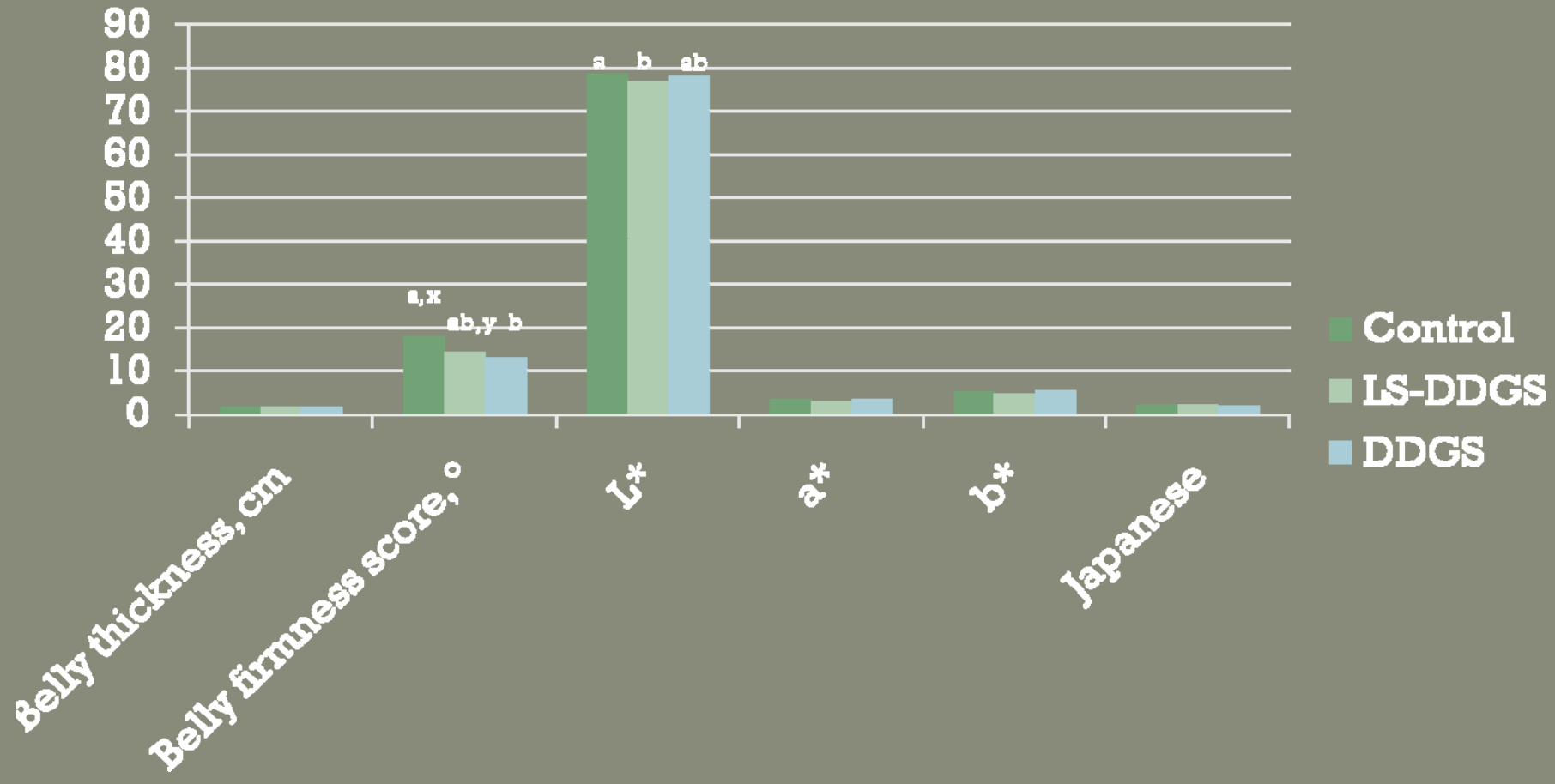
- Low solubles DDG (~8.8% fat DM basis)
- HP-DDGS (~ 3.4% fat DM basis)
- Corn germ (~19.1% fat DM basis)
- De-oiled DDGS (3-4%? DM basis)

Effect of Feeding 20% LS-DDG (8.8% Crude Fat DM basis) and 20% DDGS on Belly Fat Fatty Acid Profile



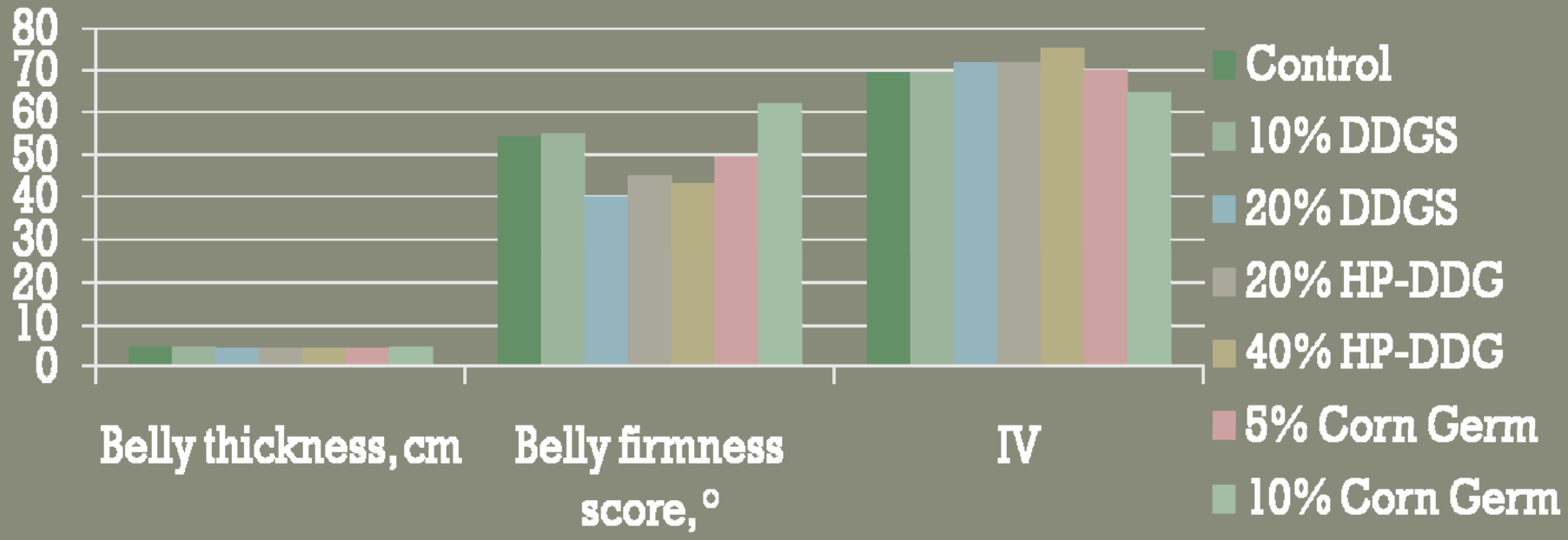
Amaral et al., 2009

Effect of Feeding 20% LS-DDG (8.8% Crude Fat DM basis) and 20% DDGS on Belly Fat Characteristics



Amaral et al., 2009

Effect of Feeding DDGS, HP-DDGS, and Corn Germ on Belly Fat Characteristics



Linear decrease in belly firmness score from increasing DDGS levels ($P < 0.02$)
Linear decrease in belly firmness score from increasing HP-DDG levels ($P < 0.06$)
Linear increase in IV from increasing HP-DDG levels ($P < 0.004$)
Linear decrease in IV from increasing levels of corn germ ($P < 0.001$)
IV of DDGS > corn germ ($P < 0.05$)

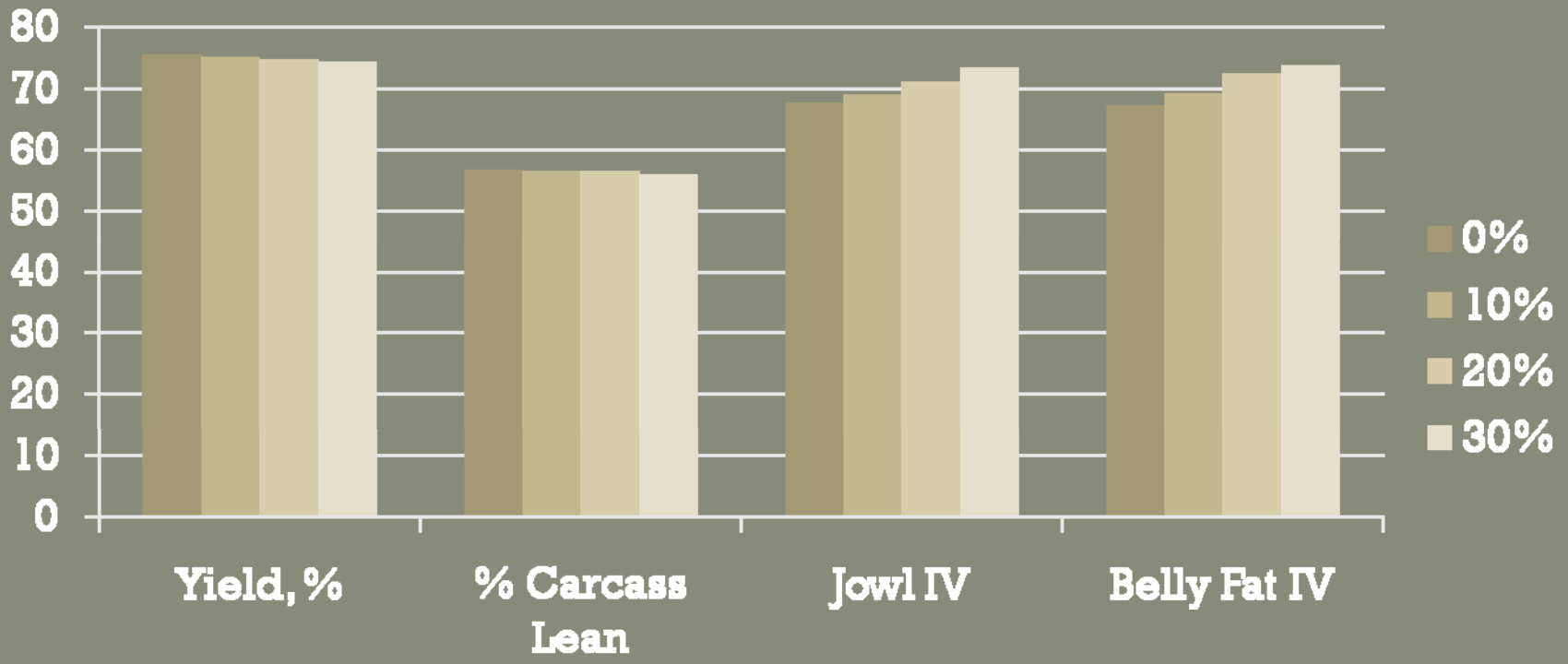
Widmer et al., 2008

Effect of Feeding DDGS, HP-DDGS, Corn Germ on Bacon and Loin QualityCharacteristics

- No effect of on:
  - cooking loss
  - shear force
  - bacon distortion score
  - overall palatabilty

Widmer et al., 2008

Effect of feeding de-oiled DDGS on yield, % carcass lean, and IV of jowl and belly fat



Linear decrease in carcass yield ($P < 0.01$)
Linear increase in jowl and belly fat IV ($P < 0.01$)

Jacela et al. (2008)

Conjugated linoleic acid

- BASF has FDA approval for use in grower-finisher diets
- Diet inclusion rate will likely be 1% (0.6% CLA) and be fed the last 10-30 days pre-harvest

$CH_3(CH_2)_5CH=CH-CH=CH(CH_2)_7COOH$

9,11-Conjugated Linoleic Acid

Conjugated linoleic acid (White et al., 2009)

- Fed 0, 20, or 40% DDGS diets during the final finishing phase
  - n = 36 pigs (12 pigs/treatment)
- Half of each group (n = 6) were fed 0.6% CLA during last 10 d pre-harvest

Conjugated linoleic acid (White et al., 2009)

- No differences in:
  - **Loin eye area**
  - **10th rib backfat depth**
  - **Last rib midline back fat depth**
  - **Loin color**
  - **Marbling**
  - **Firmness**
  - **Drip loss**
- Increasing DDGS levels increased IV and n6:n3 fatty acids
- Adding 0.6% CLA decreased IV and ratio of n6:n3 fatty acids in 20% and 40% DDGS diets
- Increasing DDGS levels decreased bacon lean:fat ratio

Effect of Dietary Crude Glycerol Level on Carcass Characteristics

	0% Glycerol	5% Glycerol	10% Glycerol
No. of pigs	30	29	31
Initial BW, kg	8.0	8.0	7.9
Final BW, kg	133	134	133
10^{th} rib backfat, mm	18.8	21.0	20.7
LM area, cm^2	48.6	49.0	46.6
Fat free lean, %	52.0	51.8	50.6
Lean gain, g/d	365	363	355
Carcass lean, %	55.7	54.7	55.7

No significant differences were observed among dietary treatments

Lammers et al., 2008

Effect of LT and ST feeding of 8% crude glycerol diets on belly characteristics

	0% Glycerol	LT Glycerol	ST Glycerol
No. of bellies	13	16	15
Adjusted belly firmness, degrees	30.3	35.3	42.3
Belly thickness, cm	3.2	3.3	3.1
Minolta L*	82.5	82.1	82.4
Minolta a*	6.6	6.6	6.4
Minolta b*	6.0	5.7	5.6

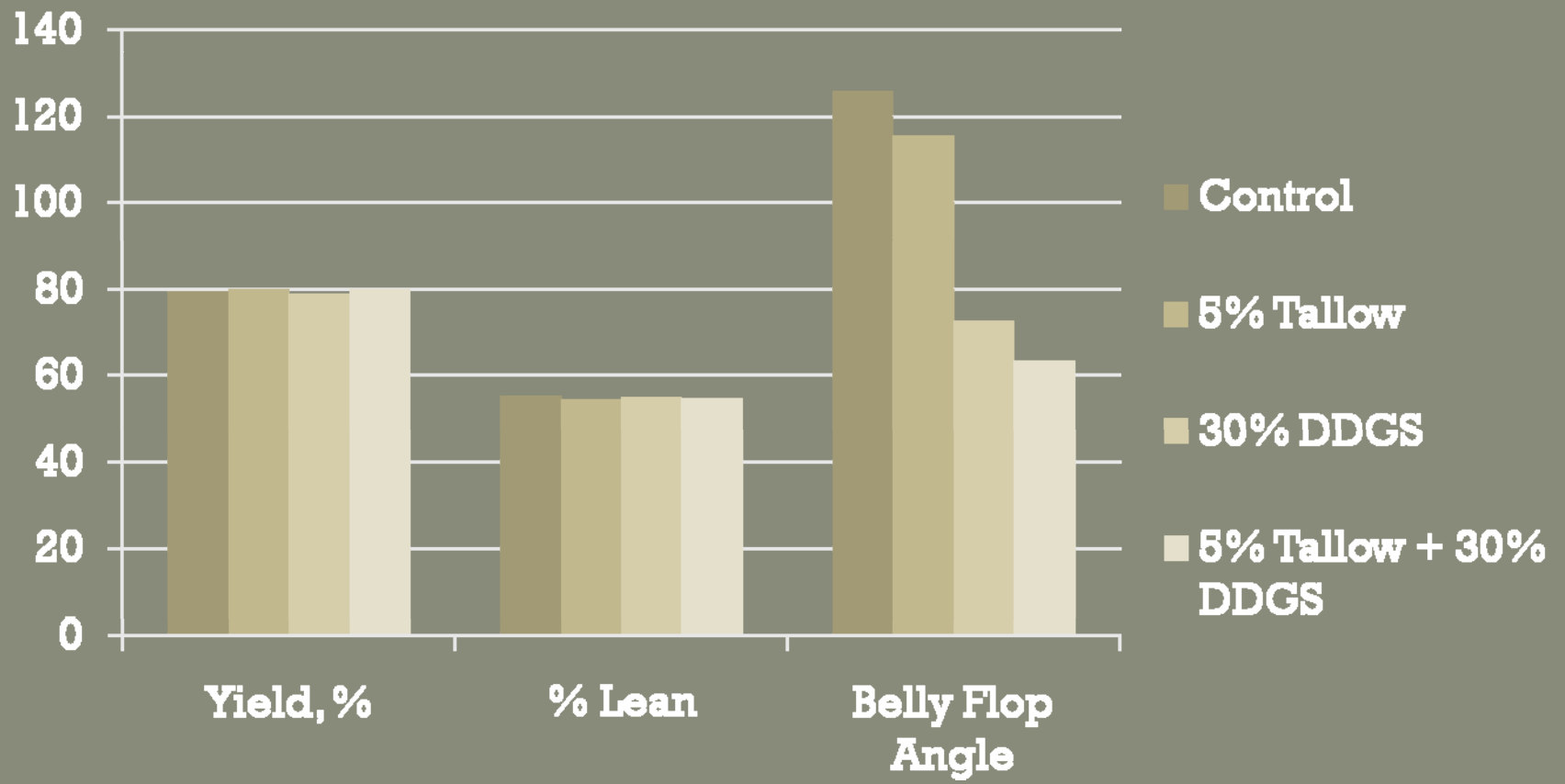
Pigs fed ST Glycerol had firmer bellies vs. control ($P < 0.05$)

Schieck et al., 2009

Comparison of fatty acid composition of selected dietary fat sources

Type of lipid	Total Unsaturated, %	Total Saturated, %	U:S ratio	Iodine Value
Beef Tallow	47.9	52.1	0.92	44
Choice White Grease	59.2	40.8	1.45	60
Corn Oil	86.7	13.3	6.53	125
Soybean Oil	84.9	15.1	5.64	130

Effect of adding % tallow to 30% DDGS diets on belly flop angle



Pomerenke et al., 2010 (unpublished)

Carcass characteristics of pigs fed liquid diets containing corn and soybean meal with either non-fermented CDS at 15% dry matter (de Lange, 2006).

	Control	Non-fermented CDS
Final body wt, kg	50.1[a]	47.5[b]
Carcass dressing, %	82.1	82.6
Backfat depth, mm	16.6	17.1
Loin depth, mm	54.3	53.7
Carcass lean yield, kg	61.1	60.9
Loin pH	5.74[a]	5.80[b]
Loin drip loss, %	9.63	8.83

[a, b] Means within rows with different superscripts differ ($P < 0.05$).

Carcass characteristics of pigs fed liquid diets containing increasing levels of phytase treated steep water (SW; de Lange, 2006).

	0% SW	7.5% SW	15% SW	22.5 % SW
No. of pens	4	4	4	4
Final body wt., kg	108.3	104.6	107.7	103.1
Carcass wt., kg	86.3	82.7	83.4	80.5
Loin depth, mm	58.2	58.9	56.4	58.3
Backfat depth, mm	18.1	18.7	18.0	17.1
Lean yield, %	60.3	60.3	60.5	60.1

Key Points

- Pork fat quality changes based on fatty acid composition of the diet
  - Dietary ingredients
    - Inclusion rates
    - Feeding period
  - Formulation strategies
- We can't afford not to feed biofuels co-products
  - Availability of supply
  - Dietary cost savings
  - BUT we need to manage increased diversity and variable nutrient composition
- How should we define acceptable pork fat quality?

Food for Thought

- Does feeding oxidized fats affect pork fat quality and safety?
  - Secondary oxidation products (HNE)
  - What are the antioxidant levels and bioavailability of corn co-products?
  - Should we be feeding higher levels of antioxidants (e.g. vitamin E)?
- What is the digestibility of free fatty acids in fat sources?
- What is the maximum level of methanol in crude glycerol that is safe?
- What impact does feeding biofuels co-products have on omega fatty acids and cholesterol content of pork?
- What are the long-term effects of feeding high levels of corn oil for choice white grease fatty acid profiles?
- What are the long-term effects of feeding high levels of DDGS to sows on sausage quality?
- Effects of Paylean and fat source and level?