Effect of supplemental vitamin C on meat quality of cattle fed varying concentrations of dietary sulfur

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Introduction

- Distillers grains are a nutritional and inexpensive alternative to corn
  - Distillers grains can be high in sulfur (S) and fat
  - Ranges include:
    - 4 - 12% fat (Stock et al., 2000)
    - S varies depending on plant
      - Can be over 1% S

Introduction

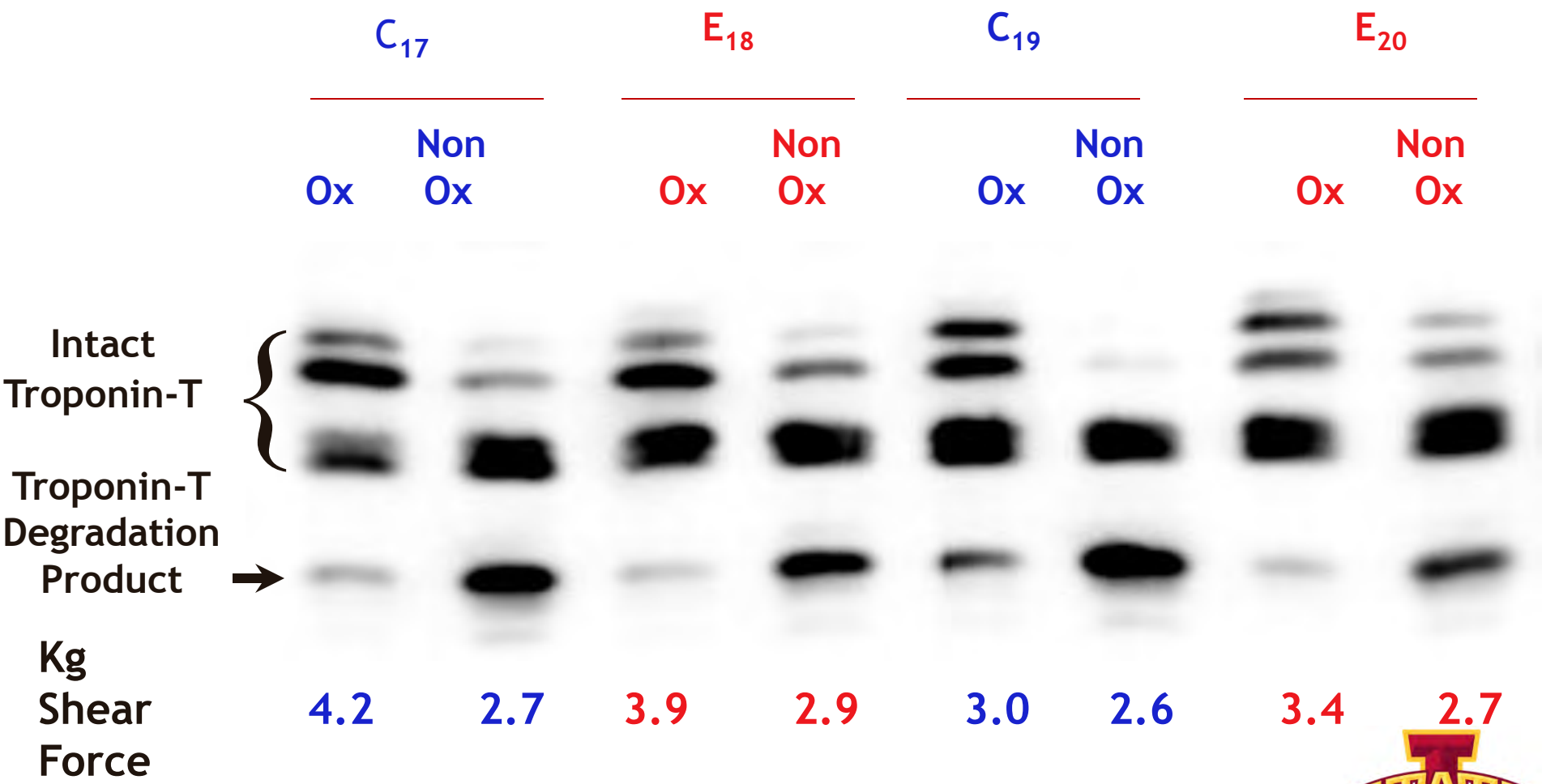
- High dietary S results in:
  - Negative impacts on feedlot performance and meat quality
    - 0.6% S decreased ADG, HCW
    - Sulfur toxicity (PEM)
    - Oxidative stress

Introduction

- Acceptance of meat products by consumers primarily related to tenderness and flavor/marbling (Miller et al., 1995)

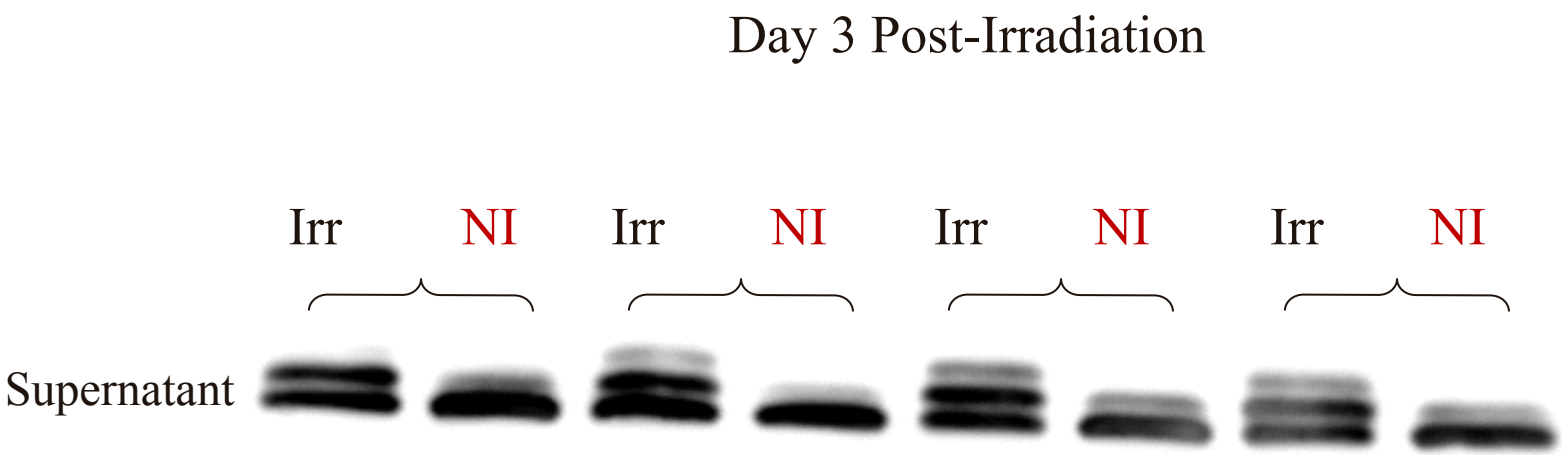
- Oxidative environment post mortem:
  - Oxidation of protease μ-calpain can limit the extent of muscle proteolysis = ↑ toughness
  - Oxidation of lipids = off flavors = ↓ shelf-life

Oxidation Slows Proteolysis and Tenderization



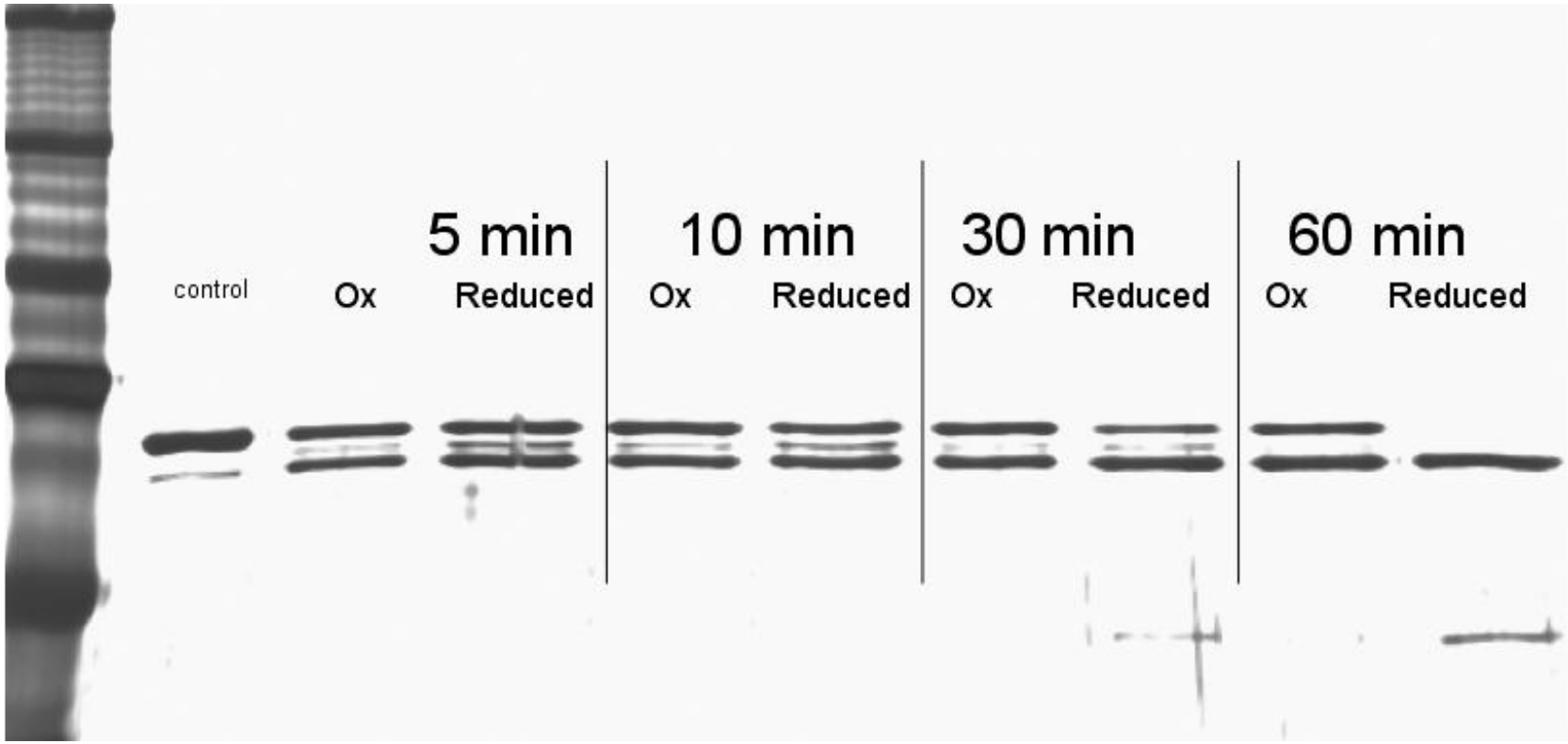
Rowe, L.J., K.R. Maddock, S.M. Lonergan, E. Huff-Lonergan. 2004. J. Anim. Sci. 82:3254-3266.

Oxidation Influences Autolysis of μ-Calpain



Rowe, L.J., K.R. Maddock, S.M. Lonergan, E. Huff-Lonergan. 2004. J. Anim. Sci. 82:3254-3266

Effect of oxidation on progression of autolysis of μ-Calpain



Ox= pre exposure to 200 μM H_2O_2;
Reduced = pre exposure to 0.1 % MCE

Lametsch, Huff-Lonergan and Lonergan. BBA Proteins and Proteomics, 1784:1215

Vitamin C Research

- Cattle synthesize ascorbate (vitamin C) in the liver
  - Roles in the body include:
    - Antioxidant function (redox reactions)
      - Regeneration of glutathione and vitamin E
    - Synthesis of collagen and carnitine
    - Enzyme cofactor

Vitamin C Research

- In vivo
  - Japanese long fed cattle (Takahashi et al., 1999; Ohashi et al., 2000)
    - Depletion of plasma vitamin C during finishing period
    - Vitamin C added late in the finishing period increased marbling scores
    - Jugular infusions of vitamin C improved color and lipid stability

- Cell culture work
  - Vitamin C enhanced adipocyte differentiation (Kawachi, 2006)

Study Objectives

- Determine the effects of supplemental vitamin C in diets containing varying concentrations of dietary S on:
    1. Performance of cattle
    2. Carcass characteristics of cattle
    3. Meat quality (protein degradation and oxidation)

Materials and Methods

- 120 steers, 5 pens/trt with 4 steers/pen
- 6 treatments

Low Sulfur, 0.2% S
- No Vitamin C
- + Vitamin C

Medium Sulfur, 0.4% S
- No Vitamin C
- + Vitamin C

High Sulfur, 0.6% S
- No Vitamin C
- + Vitamin C

- Rumen-protected vitamin C source included at 10g of vitamin C/head/day

Diet composition and analysis

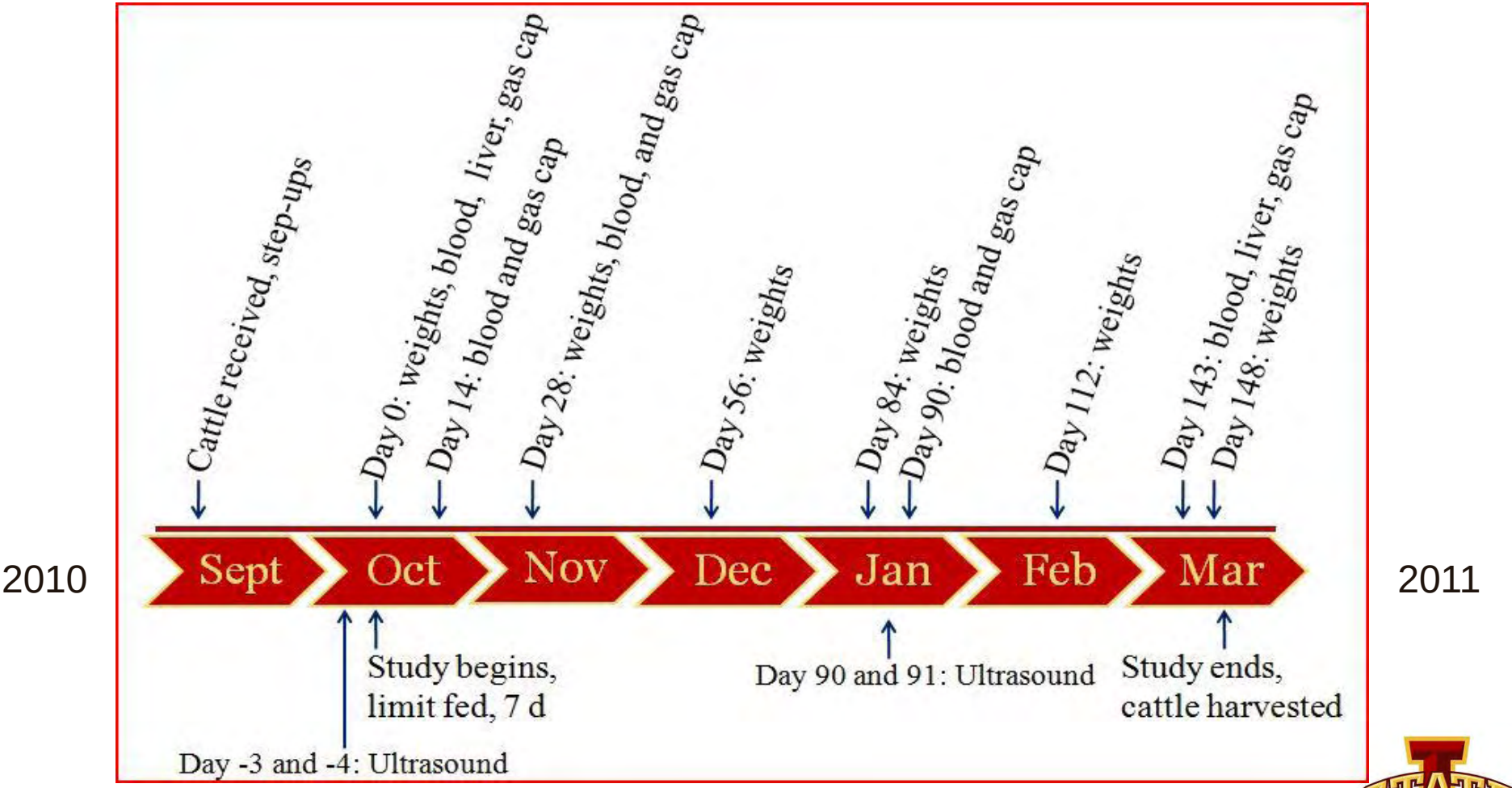
Item	Low S	Medium S	High S
Corn	69.7	48.0	48.0
Corn dried distillers grains	18.0	40.0	38.9
Chopped hay	9.0	9.0	9.0
Limestone	2.0	2.0	2.0
Salt	0.31	0.31	0.31
Vitamin A premix[1]	0.10	0.10	0.10
Trace mineral premix[2]	0.035	0.035	0.035
Rumensin90[3]	0.016	0.016	0.016
Sodium sulfate	--	--	1.11
Urea	0.8	--	--
S, %	0.18	0.32	0.56
CP, %	14.3	16.6	16.6
NEg, Mcal/kg DM	1.3	1.3	1.3

[1]Vitamin A premix contains 4,400,000 IU/kg

[2]Provided per kg of diet: 30 mg Zn as $ZnSO_4$; 20 mg Mn as $MnSO_4$; 0.5 mg I as $Ca(IO_3)_2(H_2O)$; 0.1 mg Se as Na_2SeO_3; 10 mg Cu as $CuSO_4$; and 0.1 mg Co as $CoCO_3$

[3]Provided at 27 g/ton diet

Study Timeline



Measurements taken

- Live animal:
  - BW, DMI, ADG, G:F, plasma vitamin C, plasma antioxidant capacity
- Carcass:
  - HCW, back-fat, KPH, REA, YG, QG, marbling score
- Meat Quality
  - Proximate analysis
  - Troponin-T degradation-Western Blotting
  - μ-Calpain autolysis-Western Blotting
  - Protein carbonylation-Oxi-Blots
  - Iron analysis-ICP-OES
  - TBARS
  - Fatty acid profile-GC-MS

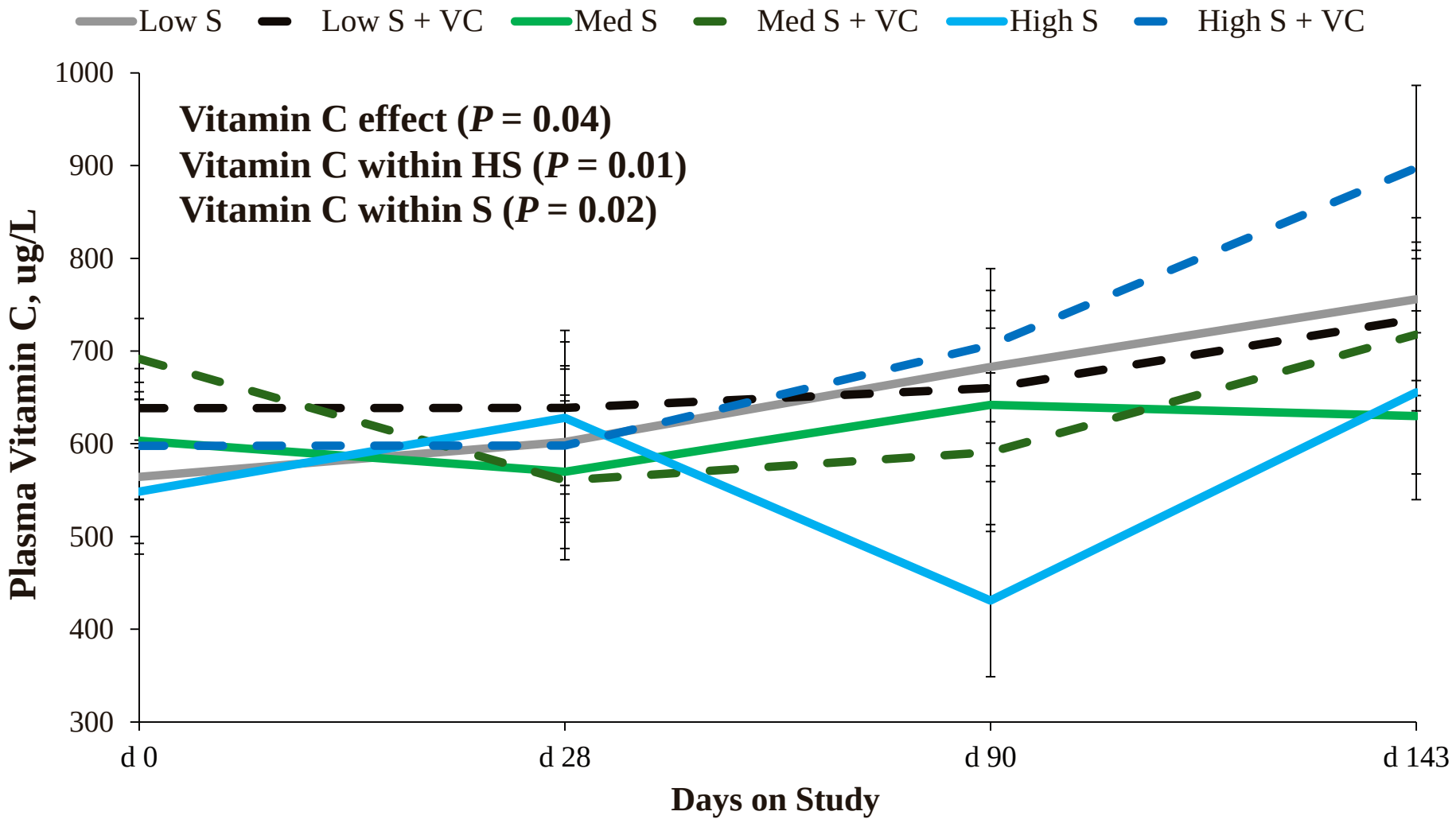
Statistical Analysis

- Contrast Statements:
  - A = Vitamin C vs. No Vitamin C
  - B = Linear effect of Sulfur
  - C = Vitamin C within High Sulfur
  - D = Vitamin C within Sulfur
  - E = Vitamin C within Corn Diet

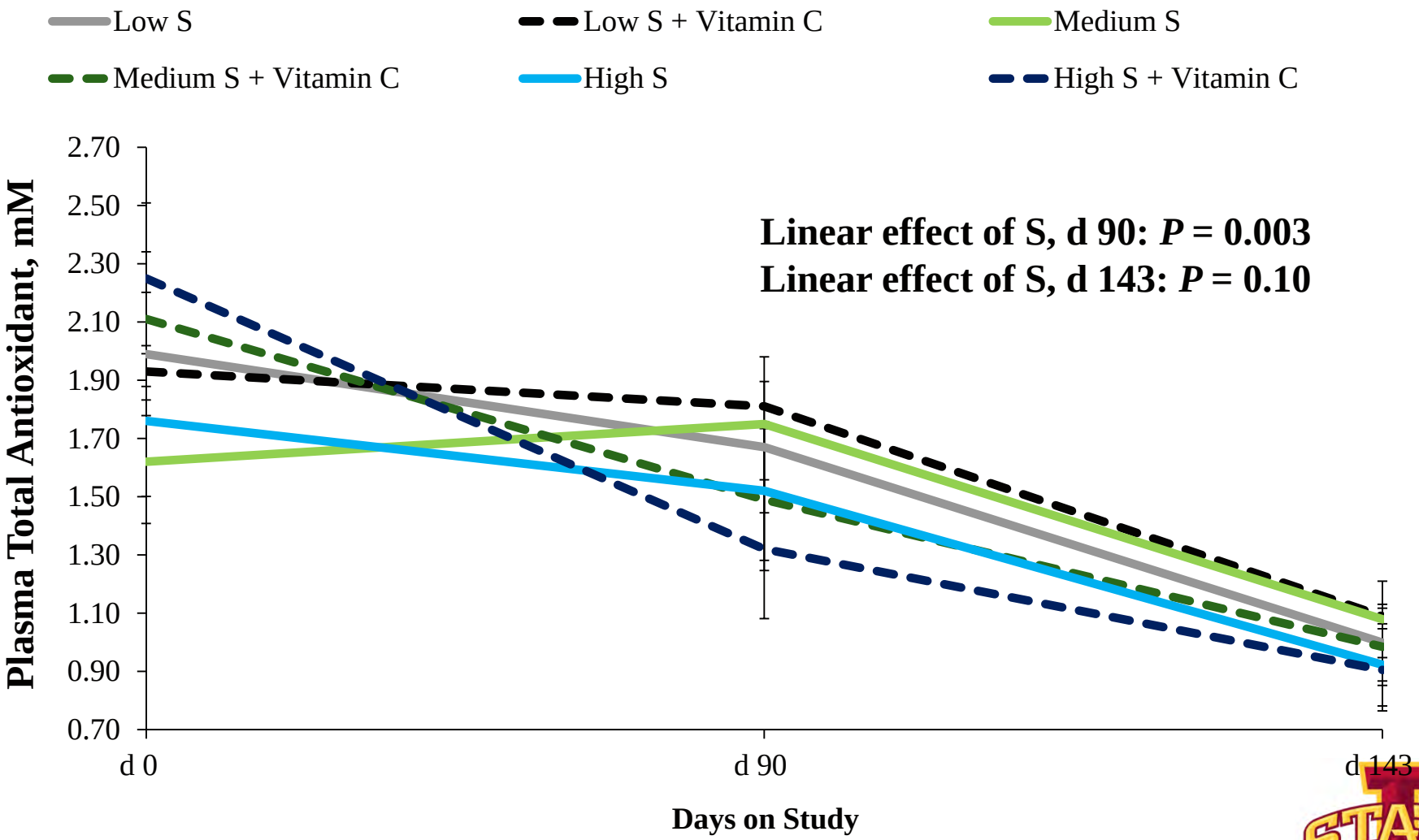
- Significance denotations:
  - †($P \leq 0.10$); *($P \leq 0.05$); **($P < 0.01$)

Results

Plasma Vitamin C



Plasma Total Antioxidant



Feedlot Performance Data

Diet S	Low		Medium		High			
Diet vitamin C	-	+	-	+	-	+	SEM	Sig[1,2]
Pen (steers)	5 (20)	5 (20)	5 (20)	5 (20)	5 (19)	5 (20)		
Initial BW, kg	342	342	341	343	340	340	10.6	
Intake								
DMI, kg/d[3]	10.54	10.50	10.82	10.20	9.41	9.73	0.32	B**
S intake, g/d[3]	21.8	22.6	34.6	33.6	53.6	57.6	1.61	B**C†
VC intake, g/d[3]	-	10.5	-	10.3	-	9.9	0.63	
Live performance[4]								
Final BW, kg	576	568	575	573	545	556	12.4	B**
ADG, kg/d	1.65	1.65	1.69	1.63	1.43	1.48	0.04	B**
G:F	0.16	0.15	0.16	0.15	0.15	0.15	0.004	

[1]Contrast Statements: A= vitamin C vs. no vitamin C; B = Linear effect of sulfur; C = vitamin C within high sulfur; D = vitamin C within sulfur; E = vitamin C within corn diet

[2]†($P \leq 0.10$); *($P \leq 0.05$); **($P < 0.01$)

[3]Month and treatment × month ($P < 0.05$)

[4]Live performance values based on measured live BW with a 4% pencil shrink applied

Carcass Data

Diet S	Low		Medium		High			
Diet vitamin C	-	+	-	+	-	+	SEM	Sig[1,2]
Pen (steers)	5 (20)	5 (19)	5 (20)	5 (19)	5 (18)	5 (20)		
HCW, kg	369	365	371	367	350	356	8.29	B**
Dressing %	64.0	64.1	64.8	65.0	64.3	64.3	0.002	
Fat, cm	1.48	1.28	1.28	1.24	1.00	1.24	0.06	B**C*D†E*
REA, cm^2	80.6	79.9	81.8	81.8	82.1	78.9	1.07	C*
KPH	2.08	2.34	2.21	2.43	2.26	2.18	0.05	A**C*D*E**
Calculated YG	3.45	3.28	3.26	3.20	2.90	3.16	0.14	B*
Marbling score[3]	511	443	474	438	398	470	13.4	B**C**E**
QG[4]	3.45	3.15	3.45	3.00	2.75	3.35	0.17	B†C*

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[3]Marbling Scores, Traces: 200, Slight: 300, Small: 400, Modest: 500, Moderate: 600

[4]Quality Grade refers to the plant assigned QG

Proximate analysis

Diet sulfur	Low		Medium		High			
Diet vitamin C	-	+	-	+	-	+	SEM	Sig[1,2]
Item								
Pen (steers)	5(13)	5(13)	5(15)	5(15)	5(14)	5(15)		
Moisture, %	71.9	72.2	72.1	72.4	73.2	73.0	0.29	B**
Fat, %	5.40	5.03	5.48	5.05	3.56	4.29	0.38	B**
Protein, %	22.3	22.1	21.5	22.0	22.3	21.9	0.10	C†

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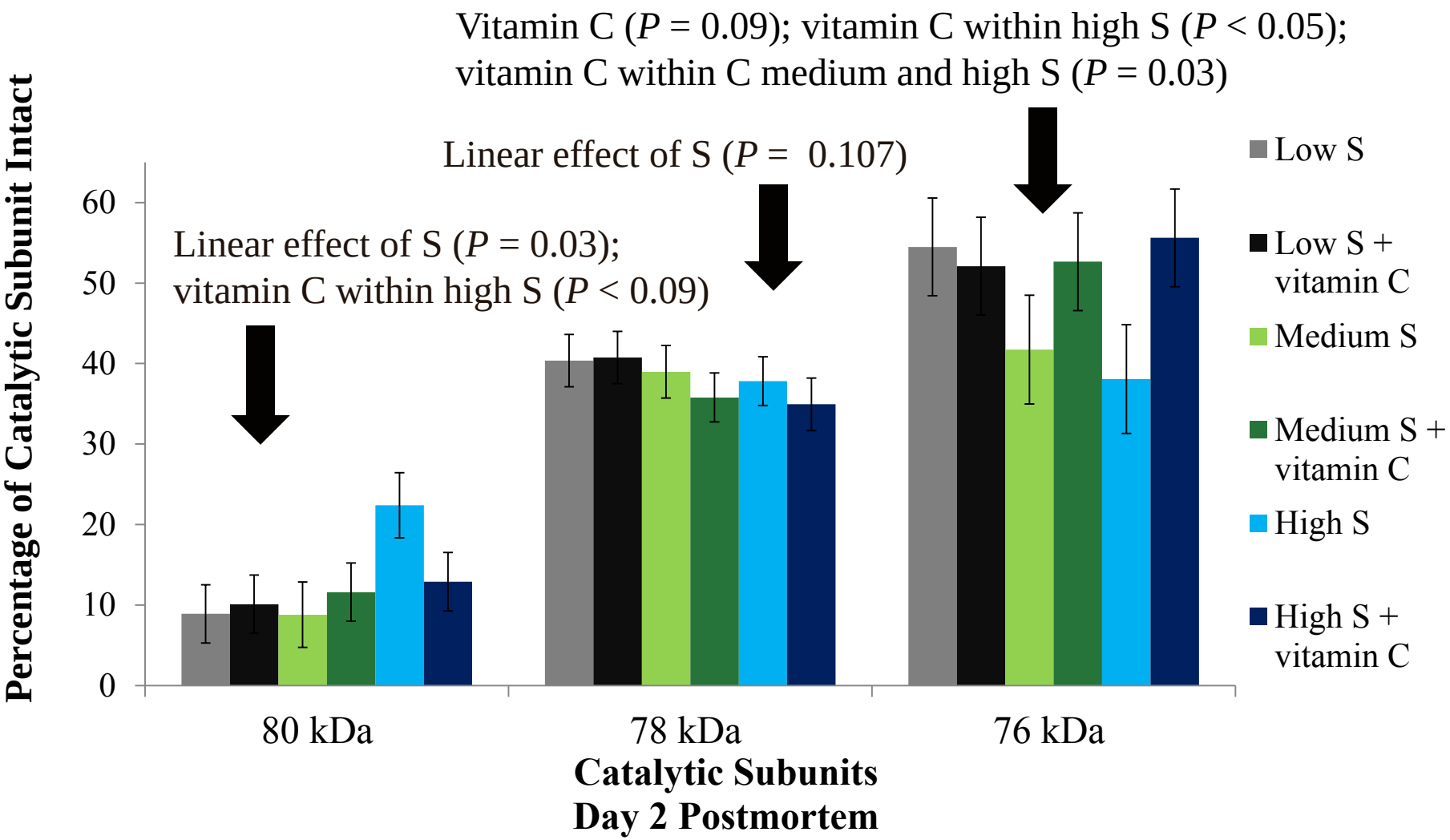
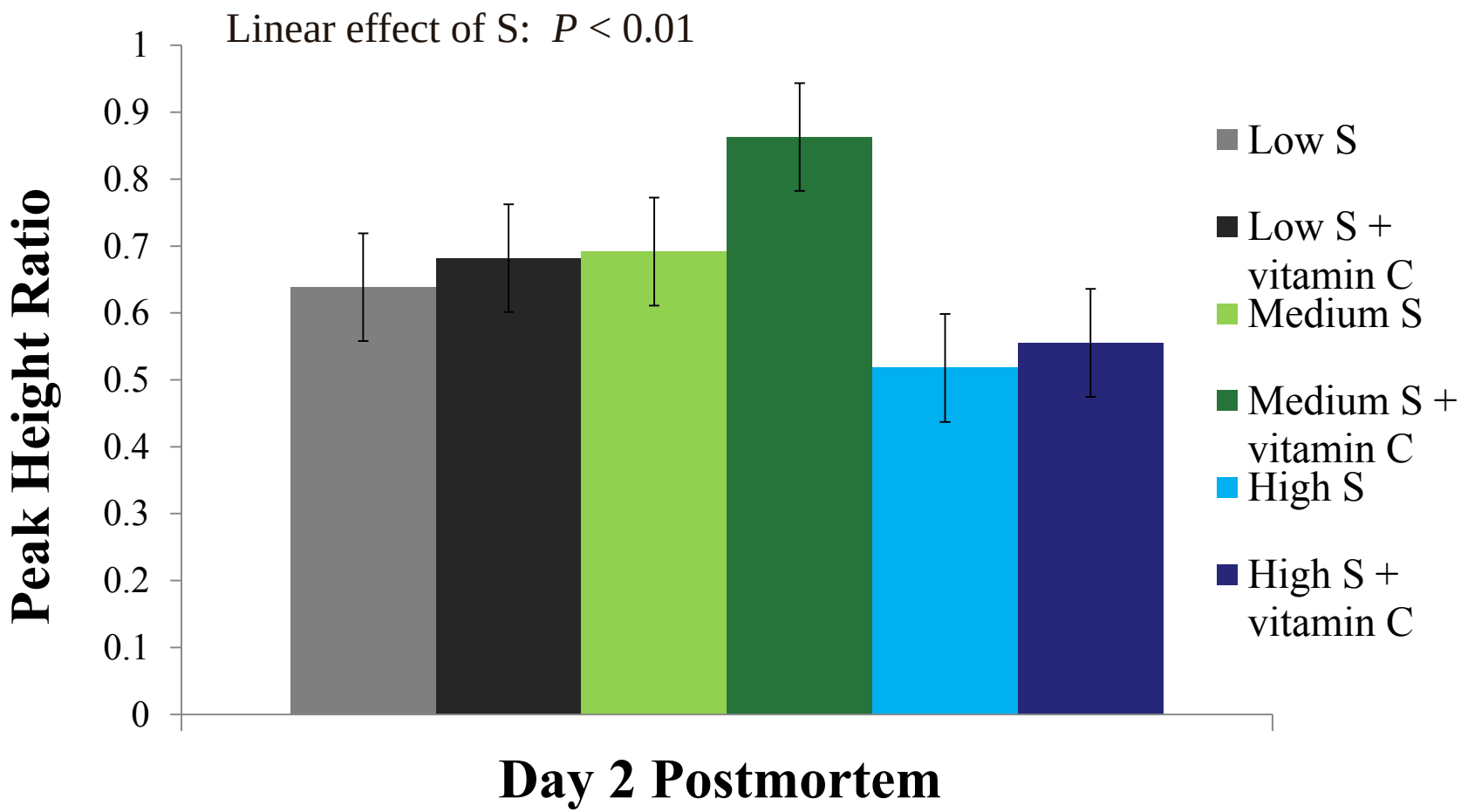
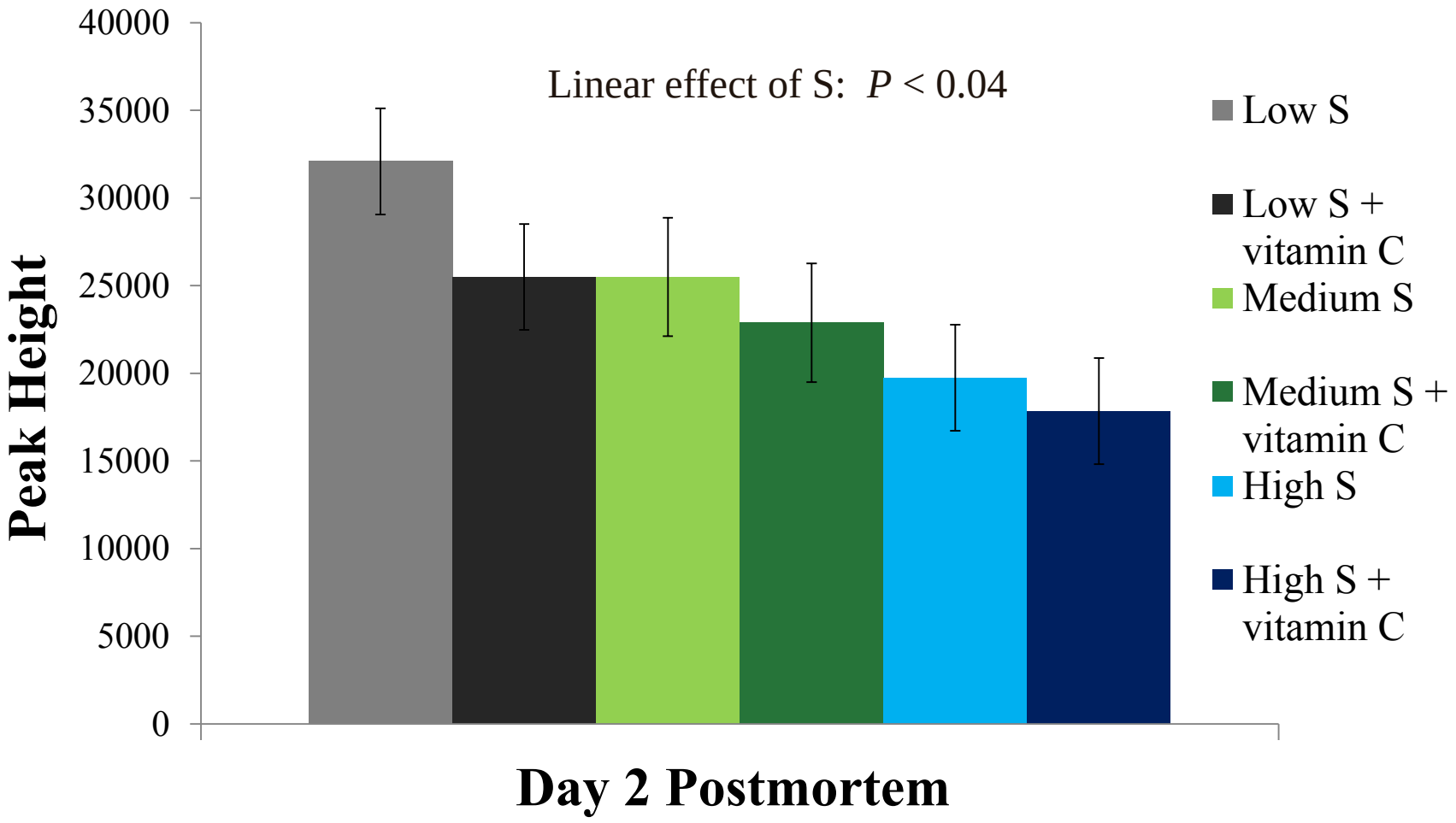
μ-Calpain autolysis



Troponin-T degradation product



Protein carbonylation



TBARS and Iron analysis

Diet S	Low		Medium		High			
Diet vitamin C	-	+	-	+	-	+	SEM	Sig[1,2]
Item								
Pen(steers)	5(18)	5(17)	5(19)	5(20)	5(18)	5(18)		
Fe, mg/kg	12.8	14.7	12.7	13.8	14.0	13.1	0.46	A†C*
Pen(steers)	5(13)	5(13)	5(12)	5(17)	5(12)	5(16)		
MDA[3], µM	0.29	0.33	0.29	0.24	0.27	0.33	0.014	A†C*E**

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[3]Malondialdehyde (lipid peroxidation product)

Summary

- Increasing dietary S
  - Decreased the presence of the 76 kDa subunit of the protease µ-calpain, troponin-t degradation, protein carbonylation, & percent fat in rib facings
  - Increased: percent protein of rib facings

- Addition of vitamin C
  - Increased marbling scores of high S cattle
  - Increased fatness of cattle
  - Increased 76 kDa subunit of µ-calpain in all treatments, but specifically noted in high S
  - Increased TBARS and Fe concentration in muscle

Conclusion and Implications

- Adding vitamin C to high S diets may increase both the quality grade and tenderness of the final meat product
- DDGS-based diets are often high in S, feeding vitamin C to cattle may allow producers enjoy the economic benefits of a DDGS-based diet while still maintaining the quality and tenderness expected by consumers

Acknowledgments

- Danielle Pogge, Ph.D. student
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