2016
Plains Nutrition Council
Spring Conference

APRIL 15-16, 2016
SAN ANTONIO, TEXAS

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2016 Plains Nutrition Council Spring Conference

Thursday, April 14

1:00 PM **Welcome and Introduction -** *Dr. Allen McDonald, Nutrition Physiology Corp., Bushland, TX*

1:15 **The NRC Requirements of Beef Cattle - An Overview of Updates and Revisions** *Dr. Mike Galyean, Texas Tech University, Lubbock*

2:00 **Research Update** – *Dr. Clint Krehbiel, Oklahoma State University, Stillwater*

2:30 **Research Update** – *Dr. Robbi Pritchard, South Dakota State University, Brookings*

3:00 **Break and Graduate Research Poster Presentations**

3:30 **Eubiotics Feeding Strategies (EFS) in the feedlot: Review of evidence of effects on performance, and mechanisms of action -** *Dr. Alfredo DiCostanzo, Univ. Minnesota, St. Paul*

4:15 **Why the Intersection of Microbiology and Neurobiology Matters to Animal Nutrition -** *Dr. Mark Lyte, Iowa State Univ., Ames*

5:15-7:00 **Research Poster Presentations and visit with presenters**

6:00-7:30 **Evening Reception** *Sponsored by* ***RAMP– Sweet Bran Cargill***

Friday, April 15

7-11:00 AM **Poster Presentations**

8:00 **PNC Business Meeting**

8:30 **Pulmonary Hypertension in Finishing Cattle -** *Dr. Joe Neary, Texas Tech University, Lubbock*

9:15 **Dr. Kenneth and Caroline Eng Foundation Graduate Student Recognition -** *Dr. Kenneth Eng, San Antonio, and Dr. Ben Holland, Cactus Feeders, Amarillo*

9:30 **Break and Graduate Research Poster Presentations**

10:00 **Fed Cattle Price Discovery and Risk Management -** *Dr. Ted Schroeder, Kansas State Univ., Manhattan*

11:00 **The Global and Domestic Economies - Influences on the US AG Sectors -** *Mr. Dan Basse, AgResource Co., Chicago*

12:00PM **Adjourn**

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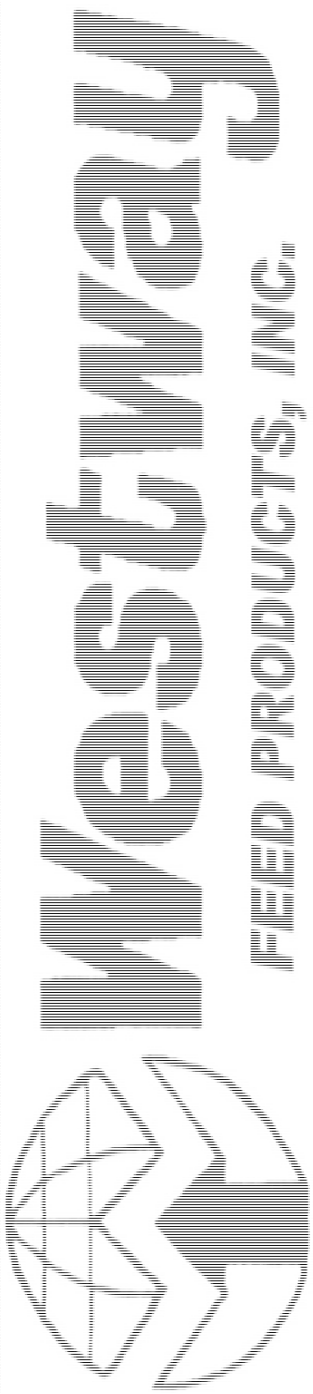
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Research Update Oklahoma State University
Growth technologies, nutrients, and management protocols used in feedlot cattle to improve health, growth performance and carcass merit

C. R. Krehbiel[1], B. K. Wilson[1], C. J. Richards[1], B. C. Bernhard[2], C. L. Haviland[1], C. A. Gifford[1], and D. L. Step[3]
[1]Department of Animal Science, Oklahoma State University, Stillwater, 74078; Department of Animal and Food Sciences, Texas Tech University, Lubbock, 79409; and [3]Department of Veterinary Clinical Sciences, Oklahoma State University, Stillwater, 74078

Introduction

Research conducted at Oklahoma State University (OSU) in the area of receiving and feedlot cattle emphasizes nutrition and management effects on health, performance and carcass merit. Recent research has evaluated: 1) management practices for producing beef using various production systems during the feedlot phase, and 2) receiving calf nutrition and health protocols to improve the health and well-being of high-risk calves. Posters related to the data discussed in this paper have been presented at previous PNC meetings by graduate students from OSU, and some of the data have been published in refereed journals as listed in the Literature Cited.

Growth Technologies

Effects of technology use in feedlot production systems on feedlot performance, carcass characteristics, and feeding behaviors of crossbred beef steers

We conducted an experiment to examine the effects of a growth technology enhanced system compared with an all-natural production program on feedlot performance, feeding behaviors and carcass characteristics. Crossbred beef steers (n = 54; initial BW = 391 ± 2.6 kg) were randomized to one of two treatments in a randomized complete block design (13 to 14 steers/pen; 27 steers/treatment). Treatments consisted of an all-natural treatment (NAT) and a conventional treatment (CONV-Z). The NAT cattle received no growth promoting technologies. The CONV-Z cattle were implanted with 40 mg of estradiol and 200 mg of trenbolone acetate on d 0, and were fed 33 and 9 mg/kg of monensin and tylosin daily, respectively, as well as zilpaterol hydrochloride (ZH) at 6.76 mg/kg (90% DM basis) for the last 20 DOF. Gain was improved by 45.1% (1.77 vs. 1.22 kg/d; $P < 0.01$) and feed efficiency by 45.5% (0.163 vs. 0.112; $P < 0.012$) for CONV-Z steers compared with NAT steers. Daily water intake was numerically greater for NAT steers compared with CONV-Z steers consistently throughout the study (56.26 vs. 53.59 L/d; $P = 0.43$). Therefore, total efficiency was improved by 50% CONV-Z steers compared with NAT steers (0.027 vs. 0.018; $P < 0.01$). Calculated dietary NE_g was improved by 30.1% for CONV-Z steers compared with NAT steers (1.34 vs. 1.03 mcal/kg; $P < 0.01$). NAT steers consumed more (8.22 vs 7.59 meals/d; $P = 0.03$), smaller feed meals (1.34 vs 1.46 kg/meal; $P = 0.02$), resulting in more time spent at the feed bunk (85.36 vs 73.19 min/d; $P < 0.01$) compared with CONV-Z steers. Water meal length was greater for NAT steers compared with CONV-Z steers (3.23 vs 2.58 min/meal; $P < 0.01$), resulting in more time spent at the water trough throughout the day (23.71 vs. 17.80 min/d; $P < 0.01$). Dressing percentage was increased by 2.17 percentage units (65.31 vs. 63.14; $P < 0.01$) for CONV-Z steers compared with NAT steers, resulting in a 48 kg heavier carcass (388 vs. 340, kg; $P < 0.01$). Marbling

score was greater for NAT steers compared with CONV-Z steers (504 vs. 410; $P < 0.01$). The results of this experiment show that CONV-Z production improves feedlot performance and carcass cutability compared with NAT with differences in feed and water intake behavior. Moreover, these data suggest that the use of technologies may improve water use efficiency, resulting in a large improvement in total feed and water resource use efficiency.

Effects of technology use in feedlot production systems on carcass value and net return
Data collected from 3 feedlot trials were used to determine the effects of conventional and natural feedlot production on carcass value and net return. Experiment 1 used 180 black-hided yearling steers. Steers were either implanted with Component TE-G (**CONV**; Elanco Animal Health, Greenfield, IN) or received no implant (**NAT**) for a grazing phase. After the grazing phase, the cattle were finished. For finishing, the 160 steers were randomized to a 2 x 2 randomized complete block design consisting of the original production system (CONV or NAT), as well as a roughage level treatment (7% diet DM [**LOW**] or 12% diet DM [**HIGH**]). The CONV steers were the animals that received the implant during the grazing phase and were fed 33 mg/kg monensin, 9 mg/kg tylosin, implanted with Component TE-S with Tylan, and fed 90 mg/hd zilpaterol hydrochloride (Zilmax, Merck Animal Health, DeSoto, KS) for the final 20 days on feed. The NAT steers were the animals that did not receive an implant during the grazing phase and were not fed monensin, tylosin, or Zilmax. All cattle were fed for 135 d, and then shipped to Creekstone Farms for slaughter. Experiments 2 and 3 used 390 black-hided crossbred steers randomized to 1 of three treatments. Treatments consisted of the NAT treatment referenced from experiment 1, as well as the CONV treatment with the feeding of Zilmax (CONV-Z) and without the feeding of Zilmax (CONV). The 390 steers used in experiment 2 and 3 were fed for an average of 132 d and were shipped to Creekstone Farms Arkansas City, KS for slaughter. Results of the economic analysis would indicate that base carcass value and Choice/Select spread play a pivotal role in determining carcass value and comparative net return. Price premiums ranging from $58.69/animal to $201.07/animal are needed to offset production costs for NAT animals compared to CONV animals, depending upon diet type, base carcass value, Choice/Select spread, and feed cost. Moreover, data indicate that HCW is the largest determining variable of carcass value. Data suggest that producers need to fully evaluate the market climate prior to the initiation of a natural program such that the producer can contract a price premium of substantial value to offset increased cost of production.

Effects of growth-promoting technologies on behavior, mobility, health parameters and heat stress of finishing steers
Crossbred steers (n=336; initial BW=379± 8kg) were utilized in a randomized complete block design to determine the effects of growth-promoting technologies on steer's behavior, mobility, health parameters and heat stress. Treatments consisted of an all-natural treatment (**NAT**), a conventional treatment (implanted with 40 mg of estradiol and 200 mg of trenbolone acetate (TBA), and fed 33 and 9 mg/kg of monensin and tylosin daily, **CONV**) and a CONV treatment plus the addition of zilpaterol hydrochloride (ZH; at 6.9 g/ton (90% DM-basis) for the last 20 days on feed with a 3-4 d withdrawal; **CONV-Z**). Chute exit scores resulted in a treatment time interaction ($P = 0.03$), with NAT steers having a more aggressive exit score than CONV and CONV-Z steers at d 10Z and d 20Z. There were no effects of treatment on exit velocity, pen temperament, or overall temperament ($P \geq 0.26$). Standing time and lying bouts were not affected by treatment ($P > 0.45$), but CONV-Z steers took more steps/d ($P = 0.04$), resulting in a

greater motion index ($P = 0.05$) than NAT steers. While moving to the working facilities, CONV-Z steers moved at the slowest velocity, CONV were intermediary, and NAT the fastest ($P < 0.05$). Step length and mobility scores were not affected by treatment ($P \geq 0.14$). White blood cells were greater for CONV and CONV-Z versus NAT steers from d 28 through d 20Z ($P < 0.05$). Liver abscesses, lung scores and heart and liver histologic changes were no affect by treatment ($P \geq 0.10$). During summer heat stress, body temperature was not affect ($P > 0.10$), but respiration rate was greatest for CONV-Z steers, intermediate for NAT and lowest for CONV steers ($P < 0.05$). Hair covering score were reduced for CONV and CONV-Z versus NAT cattle from d 84 through d 20Z. The results of this experiment suggest that growth-promoting technologies have little to no overall effects on cattle behavior, mobility and health parameters. Treatment altered the mechanism by which steers exchange heat load to maintain thermo-homeostasis, but all steers experienced a similar magnitude of heat stress. Collectively, conventionally utilized growth-promoting technologies did not have a negative effect on finishing steer well-being during this study.

Nutrients

Effect of copper, manganese, and zinc supplementation on the performance, clinical signs, and mineral status of calves following exposure to bovine viral diarrhea virus type 1b and subsequent *Mannheimia haemolytica* infection (Wilson et al., 2016)

Research has indicated that trace mineral (TM) supplementation may alter immune function and reduce morbidity associated with bovine respiratory disease. The objective of this experiment was to determine the influence of dietary Cu, Mn, and Zn supplementation on the performance, clinical signs, and TM balance of calves following a bovine viral diarrhea virus (BVDV) and *Mannheimia haemolytica* (MH) combination respiratory pathogen challenge. Steers ($n = 16$; 225 ± 20 kg BW) from a single ranch were processed, weaned, and randomly pairwise assigned to either the TM-supplemented (MIN) or the control (CON) experimental treatments. The MIN calves received an additional 150 mg of Cu, 130 mg of Mn, and 320 mg of Zn daily and the CON calves received the basal diet with no additional Cu, Mn, or Zn supplementation. The basal diet contained sufficient Mn and Zn but inadequate Cu based on published nutrient requirements. After 46 d on the experimental treatments, all calves were naturally exposed to a heifer persistently infected with BVDV type 1b for 4 d and then subsequently intratracheally challenged with MH. Data were analyzed using the GLIMMIX procedure of SAS with sampling time serving as a repeated measure and calf serving as the experimental unit. The respiratory challenge was validated via increased BVDV type 1b antibody concentrations, MH whole cell and leukotoxin antibody concentrations, rectal temperatures (TEMP), and subjective clinical severity scores (CS). Calf performance ($P \geq 0.48$) was not affected by TM supplementation. Mineral supplementation also did not impact the CS or TEMP of calves ($P \geq 0.53$). There was a treatment × time ($P < 0.001$) interaction observed for liver Cu concentrations. The concentrations of Cu, Mn, Zn, and Fe within the liver; Cu, Mn, and Zn within the muscle; and Cu, Zn, and Fe within the serum were all impacted by time ($P \leq 0.03$). Calves receiving the MIN treatment had greater ($P < 0.01$) liver Cu and Mn concentrations compared with CON calves. In contrast, serum Cu and Fe concentrations were increased ($P \leq 0.05$) in CON calves compared with MIN calves. Mineral supplementation did not impact TM concentrations within the muscle ($P \geq 0.38$). The supplementation of Cu, Mn, and Zn can improve the Cu and Mn status within the liver and serum of calves in response to a BVDV and MH challenge. When Cu is supplemented

to calves receiving a marginally Cu-deficient diet, Cu status within the body is significantly improved.

Management Protocols

Evaluation of multiple ancillary therapies utilized in combination with an antimicrobial in newly received high-risk calves treated for bovine respiratory disease (Wilson et al., 2015)
Ancillary therapy (ANC) is commonly provided in conjunction with an antimicrobial when treating calves for suspected BRD. This experiment evaluated the effects of 3 ANCs in combination with an antimicrobial in high-risk calves treated for BRD. Newly received crossbred steers (n = 516; initial BW = 217 ± 20 kg) were monitored by trained personnel for clinical signs of BRD. Calves that met antimicrobial treatment criteria (n = 320) were then randomly assigned to 1 of 4 experimental ANCs: intravenous flunixin meglumine injection (NSAID), intranasal viral vaccination (VACC), intramuscular vitamin C injection (VITC), or no ANC (NOAC). Steers receiving VACC tended ($P = 0.10$) to require a second BRD treatment less frequently than steers receiving NSAID or NOAC. Calves receiving NSAID or VITC tended ($P = 0.09$) to require a third BRD treatment less often than calves receiving NOAC. Of calves treated 3 times for BRD, those receiving NOAC had lower ($P = 0.05$) severity scores than those receiving VACC or VITC and heavier ($P = 0.02$) BW than those receiving NSAID, VACC, or VITC at the time of third treatment. Between the second and third BRD treatments, calves receiving NOAC also had greater ($P = 0.03$) ADG than those receiving VACC or VITC and tended ($P = 0.06$) to have greater ADG than those receiving NSAID. Calves receiving NOAC tended ($P = 0.07$) to have heavier BW on d 28 than NSAID, VACC, or VITC with mortalities and removals excluded. There was no difference in rectal temperature among the experimental ANCs. When contrasted with the average of NSAID, VACC, and VITC calves receiving NOAC tended to have heavier BW on d 56, greater ADG and DMI from first BRD treatment through d 28, greater DMI from d 28 through d 56, and had greater DMI from first BRD treatment through d 56 with mortalities and removals excluded ($P = 0.06$, $P = 0.10$, $P = 0.08$, $P = 0.06$, and $P = 0.05$ respectively). After the receiving period, a subset of calves (n = 126) were allocated to finishing pens to evaluate the effects ANC administration on finishing performance, carcass characteristics, and lung scores. No ANC differences were observed for any of the variables analyzed in the finishing study ($P \geq 0.26$). Responses observed to the 3 ANCs utilized in these experiments were negligible. The use of NSAID, VACC, and VITC do not appear to positively impact clinical health and could potentially be detrimental to performance during the receiving period in severely immune-challenged calves.

Impact of bovine respiratory disease during the receiving period on steer finishing performance, efficiency, carcass characteristics, and lung scores
Bovine respiratory disease (BRD), also known as "shipping fever" or bronchopneumonia, is the most significant production problem for the feedlot industry, accounting for the majority of morbidity, mortality, decreased production, and economic losses in feedlots. The objective of this experiment was to evaluate the effect of BRD incidence during the receiving period on subsequent finishing performance, efficiency, carcass characteristics, and lung scores of feedlot steers. Prior to the initiation of this experiment, some calves were enrolled in an experiment evaluating ancillary therapy use. During the receiving period, crossbred steers (n = 516; initial BW = 217 ± 20 kg) were monitored daily by trained personnel for clinical signs of BRD. Overall

morbidity and mortality attributed to BRD were 66.5% and 13.2%, respectively. After the receiving period, a subset of calves (n = 174) were grouped by previous experimental treatment and the number of times treated for BRD (BRDX) and allocated to finishing pens. The BRDX experimental groups included: never treated for BRD (0X), treated 1 time (1X), 2 times (2X), or 3 or 4 times (3/4X). Arrival BW did not differ among calves utilized in this experiment (P = 0.17). However, BRDX during the receiving period decreased calf performance, resulting in BW of 324, 316, 285, and 260 kg for 0X, 1X, 2X, and 3/4X, respectively, at the start of the finishing phase ($P < 0.001$). Ultrasound estimates, BW, and visual appraisal were used to target a common compositional end point based on 12th rib fat thickness (average days on feed; DOF = 182) for each pen of cattle. There was no difference ($P \geq 0.83$) in 12th rib fat thickness among BRDX at harvest. Data were analyzed using the MIXED procedure of SAS with pen (n = 32; 8 per BRDX group) serving as the experimental unit. The lack of significant interactions between BRDX and previous experimental ancillary therapy treatments allowed for the integrity of both experiments to be maintained. With increasing BRDX, DOF and lung consolidation scores increased linearly ($P \leq 0.003$), while HCW, dressing percentage, rib eye area (REA), and the percentage of USDA Prime and Choice carcasses decreased linearly ($P \leq 0.03$). These results suggest that with additional DOF, calves treated multiple times for BRD are able to reach similar compositional end points as their untreated cohorts; however, it may not be possible for these calves to ever reach the same quality and yield potential.

Literature Cited

Wilson, B. K., D. L. Step, C. L. Maxwell, J. J. Wagner, C. J. Richards and C. R. Krehbiel. 2015. Evaluation of multiple ancillary therapies used in combination with an antimicrobial in newly received high-risk calves treated for bovine respiratory disease. J. Anim. Sci. 93:3661-3674.

Wilson, B. K., M. Vazquez-Anon, D. L. Step, K. D. Moyer, C. L. Haviland, C. L. Maxwell, C. F. O'Neill, C. A. Gifford, C. R. Krehbiel and C. J. Richards. 2016. Effect of copper, manganese, and zinc supplementation on the performance, clinical signs, and mineral status of calves following exposure to bovine viral diarrhea virus type 1b and subsequent *Mannheimia haemolytica* infection. J. Anim. Sci. 94:1123-1140.

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Research Update from South Dakota State University

R. H. Pritchard

Backgrounding phase ADG influences on finishing phase steer performance and carcass traits

It is widely acknowledged that early growth and backgrounding phases of cattle production influence performance during the finishing phase and can impact carcass traits. Distilling optimal backgrounding management is complicated because of the many different variables involved. The growth rate allowed, the duration of time at that growth rate, the window of the growth curve included during backgrounding, fill, and days or body weight or fatness endpoints of the finishing phase all influence interpretation of the existing data. Additionally it remains unresolved whether it is CHO source or caloric intake that most influences eventual carcass fat distribution.

This study was designed to measure the influence of backgrounding ADG (2.0, 2.5, or 3.0 lb) on subsequent production variables. The window of the growth curve targeted was from 50% to 65% of FSBW. Subsequent finishing performance and carcass traits were evaluated when treatments were terminated at a constant fat endpoint typical of the industry (0.55). To minimize confounding of CHO source verses calories effects on intramuscular adipose accretion, intake of a common corn silage and grass hay based diet was fed at prescribed levels to achieve targeted backgrounding ADG. Three different supplements were used depending on intake prescription to balance for CP, minerals, vitamins and monensin. The backgrounding diet NEg was formulated at 49 Mcal NEg/cwt. There were 10 pens of 8 steer calves assigned to each treatment. Steers were implanted with Synovex S (backgrounding) and Revalor-S during the finishing phase of the study.

Increasing the backgrounding ADG caused linear declines ($P<0.05$) in finishing phase ADG and DMI (Table 1). When backgrounding ADG was limited to 2.2 lb the F/G was increased by 6.4 % over the higher ADG treatments ($P<0.05$). When harvested at a constant fatness, higher backgrounding ADG caused linear declines ($P<0.05$) in finished weight and HCW. Marbling responded in a quadratic fashion ($P<0.01$) with peak marbling associated with backgrounding ADG of 2.5 lb. These response curves will aid in the development of optimized backgrounding strategies for specific production and carcass targets.

Managing caloric intake and implant potency when finishing steers

Total LWG and F/G are primary determinants of profitability of finishing cattle. Limits on feeding endpoints are body weight and/or fatness. This study was designed to measure whether managing growth rate and anabolic agent dosage could be used to optimize total LWG, F/G and carcass value in finishing steers. Treatments included 2 implant strategies: a) Synovex Plus on d 1 and b) Synovex Choice on day 1 and day 63. This represents equal total anabolic exposure (mg), but with a redistribution of payout. There were 2 feeding strategies employed: a) fed ad libitum throughout and b) restricted intake such that ADG would not exceed 4 lb/d during the initial 63 d on feed. There were 24 pens of 8 steers on feed for 125d in this study. Treatments were arranged as a 2 x2 factorial.

Table 1. Backgrounding ADG impact on finishing performance and carcass traits

	Target Background ADG				
	2.0	2.5	3.0	SEM	
Bkgd					
Initial BW,	675	673	675	0.9	
End BW, lb	880[b]	872[a,b]	865[a]	2.9	
ADG, lb	2.22[a]	2.54[b]	3.04[c]	0.040	Linear *P*<.01
DMI, lb	16.46	18.31	19.90	0.072	Linear *P*<.01
Days	93	79	63		
Finishing					
End BW, lb	1371[b]	1354[b]	1314[a]	8.1	Linear *P*<.05
ADG, lb	4.09[c]	3.90[b]	3.58[a]	0.058	Linear *P*<.05
DMI, lb	24.41[c]	23.08[b]	22.57[a]	0.150	Linear *P*<.05
F/G	6.34[b]	5.93[a]	5.98[a]	0.082	
Days	122	125	127		
RIbfat, in	0.54	0.55	.055	0.016	
HCW	856[c]	846[b]	821[a]	5.0	Linear *P*<.05
Marbling[1]	554[b]	587[a]	578[a,b]	9.4	Quadatic

[1] 400 = Slight[0]; 500 = Small[0]

Table 2. Caloric Intake and Implant Strategy

Implant	Synovex Plus		Choice - Choice		
Intake	Ad lib	Early Cap	Ad lib	Early Cap	SEM
Initial BW, lb	827	823	827	825	0.3
Final BW,	1370[a]	1355[b]	1348[b]	1369[a,b]	8.9
ADG, lb†	4.34	4.23	4.17	4.36	0.070
DMI, lb†‡	23.81[a]	22.75[b]	22.92[b]	23.12[b]	0.209
F/G‡	5.48[a]	5.38[a,b]	5.50[a]	5.31[b]	0.059
Dress, %‡	62.55	62.97	62.56	63.02	0.166
HCW, lb†	856	846	843	856	5.5
REA, in2	14.0[a,b]	14.3[a]	13.8[b]	14.0[a,b]	0.15
Ribfat, in	0.53	0.54	0.55	0.57	0.015
Marbling [1] ‡	576[a]	551[b]	573[a]	564[a,b]	5.7

[1] 400 = Slight[0]; 500 = Small[0]

[a, b, c] means without commons superscripts differ (P<0.05)

† Implant x Intake interaction (P<0.05)

‡ Diet effect (P<0.05)

Capping NEg intake (Intake) during the initial 63 d on feed resulted in a lower cumulative DMI ($P<0.05$). Neither Implant nor Intake affected cumulative ADG ($P>0.20$) but there was an Implant x Intake interaction ($P=0.05$) for ADG. Capping Intake of steers implanted with Synovex Plus and ad libitum intake of steers receiving Synovex Choice resulted in lower ADG than the 2 other simple effect means. Feed efficiency was improved ($P<0.05$) by capping early intake. Capping early caloric intake resulted in a higher Dress% ($P<0.05$) which is difficult to explain since DMI was similar in latter stages of feeding and rib fat and KPH were similar across Intake. The Implant x Intake interaction evident for ADG was also evident for HCW, where steers fed ad libitum with Synovex Plus and steers receiving 2 Synovex Choice implants in conjunction with capped early intake yielded heavier ($P<0.05$) HCW than the other 2 treatments. Capping early NEg intake lowered marbling scores ($P<0.05$) and this impact was predictably most pronounced when Synovex Plus was administered on d 1. This study demonstrates that discriminate use of implants and dietary energy management can be used to optimize for varying economic priorities for total live weight gain, feed efficiency, and Quality Grade.

Current and Ongoing Activities

- Statistical and methodology challenges of small pen studies
- Chromium influences on production traits, insulin sensitivity, and gene expression
- Capsicum oleoresin supplementation in finishing diets
- Dietary LCFA influences on intramuscular adipose tissue development

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Eubiotics Feeding Strategies (EFS) in the feedlot: Review of evidence of effects on performance, and mechanisms of action

N. Kenney-Rambo, K. Nenn and A. DiCostanzo
University of Minnesota

Introduction

Eubiotics (from Greek, eu: good or healthy and bios: life) is a term gaining use in the food industry as the science of hygienic or healthy living; a caveat added is the reference to a healthy balance of the micro-flora of the intestinal tract. Evidence from human medical research supports the notion that an imbalance of the micro-flora of the intestinal tract is represented by, if not associated with, disease conditions in humans (You and Sherman, 2015). Perhaps these findings support why in spite of living longer (one would allege thereby achieving eubios) a proportion of the American population believes we lead unhealthy lives and, eubiotics is the path we must follow to remedy many of our ills.

Concurrently, upcoming implementation of the Veterinary Feed Directive (VFD) is more than a sign of changes ahead in livestock production practices; it is the first taste of reality. Many may argue that we are on a slippery slope: this is the beginning of the end for the industry to access conventional antimicrobial feeding strategies. Yet, one thing is clear: the US beef industry is responding to consumer choice and offering more USDA certified beef programs where use of antibiotics is either eliminated or limited. Concurrently, proportion of feedlots using ionophores decreased from 97.3% in1994 to 90.5% in 2011 (USDA NAHMS, 2013).

Arguing whether American population eubios is better reached by conventional or alternative living and eating practices is beyond the scope of this paper. Providing the reader with a scientific review of the evidence arising from research on alternative feed additives with potential eubitoic effects on cattle performance and proposed mechanisms of action is the objective of this contribution. Efforts were made by the authors to evaluate effects of yeast, yeast culture, bacterial and enzyme preparations on feedlot performance in a systematic review of literature aided by a meta-analysis approach if sufficient data was available from refereed manuscript, university reports and dissertations. Effects of polyclonal antibodies and proprietary preparations of eubiotic combinations from the list above were referenced conventionally. Brief reference was made to mechanism of action to inform the reader of possible negative associative effects under certain dietary and environmental applications. A list of products that may be collectively referred to as eubitoic and currently FDA-approved ionophores and antibiotics for reduction of liver abscesses are listed in the next section (Table 1).

DFM, Fermentation Products and Conventional Feed Additives

For regulation purposes, DFM (direct-fed microbial) is the official definition (CPG Sec. 689.100 Direct-Fed Microbial Products) granted by FDA to products that are purported to contain live (viable) micro-organisms (bacteria or yeast). The Association of American Feed Control Officials (AAFCO) describes yeast and yeast culture under section 96, and bacterial and mold ingredients under fermentation products (section 36) of the AAFCO Official Publication. Upon

review of this contribution or further study of DFM or fermentation products, the reader must remain aware that under FDA policy, 1) DFM products listed by the AAFCO Official Publication and labeled with the AAFCO-approved label statement for live microorganism content or 2) a product containing microorganisms listed by the AAFCO Official Publication but not purported to contain live microorganisms and with no label/promotional representations other than as a source of designated nutrients, and not labeled or promoted with any therapeutic or structure/function claims, will be regulated as a food as defined in Section 201(f)(3) and usually will not require FDA regulatory attention. However, if FDA has safety concerns about these products, it will treat them as not generally recognized as safe and will regulate them as food additives subject to FDA enforcement attention.

Table 1. Direct-fed microbials and fermentation products and FDA-approved ionophores and liver abscess preventive antibiotics for feedlot use

Product	Class	Active ingredient [a]	FDA Indications
Antibiotic	Macrolide	Tylosin	Reduction of incidence of liver abscesses
Antibiotic	Tetracycline	Chlortetracycline	Reduction of liver condemnation due to liver abscesses
Antibody	Polyclonal antibody	Ig Y	None
DFM	Bacterial preparation	*Lactobacillus acidophilus*	None
DFM	Bacterial preparation	*Propionibacterium freudenreichii*	None
DFM	Bacterial preparation	*Enterococcus faecium*	None
DFM	Bacterial preparation	*Megasphaera elsdenii*	None
DFM	Yeast	*Saccharmoyces cerevisiae*	None
Essential oils	Essential oils		None
Fermentation product	Enzyme extract	*Aspergillus oryzae*	None
Fermentation product	Yeast culture	*Saccharmoyces cerevisiae*	None
Ionophore	Crown ether	Monensin sodium	Improve feed efficiency
Ionophore	Crown ether	Laidlomycin propionate potassium	Improve feed efficiency and increased rate of weight gain
Ionophore	Crown ether	Lasalocid sodium	Improve feed conversion and rate of weight gain

[a] Not a complete list.

Because conventional feedlot production practices are based on use of ionophores and liver abscess preventive antibiotics (USDA NAHMS, 2013), a discussion of alternative strategies

either in support or in substitution of conventional production practices would not be complete without establishing a baseline of the impact of ionophores and liver abscess preventive impact on feedlot performance. Therefore, if alternative feed additive solutions are to be used in conjunction with or in substitution of existing feed additives, they would need to meet certain minimum requirements of which maintaining cattle performance at levels expected for conventional feed additives may only be one of the considerations. In an effort to lead the reader to reflect on a holistic evaluation of alternative feed additives presented in the following sections, a list of the ideal feed additive, based on the feedlot industry experience with conventional feed additives, is drawn in Table 2.

A meta-analysis of effects of monensin on performance of feedlot cattle published nearly 10 yr after the molecule was FDA approved (Goodrich et al., 1984) demonstrated that cattle fed monensin had 7.2% improved feed conversion with 2.7% lower DMI. Later, using a meta-analysis approach evaluating all three ionophores listed in Table 1, DiCostanzo et al. (1997) reported that feedlot cattle fed laidlomycin, monensin or lasalocid required less feed DM/unit gain. This reduction resulted in improvements in feed efficiency of 5.4%, 4.6%, 5.7% and 6.7% for laidlomycin, lasalocid, monensin or monensin plus tylosin, respectively. Given differences in feed DM unit/unit gain for cattle fed no ionophore in these studies, it behooves the authors to present reductions in feed DM unit/unit gain as absolute values; 0.58 (Goodrich et al., 1984) and from 0.29 to 0.46 feed DM unit/unit gain (DiCostanzo et al., 1996). Recent reports on the impact of ionophore feeding on feed conversion revealed that both monensin and laidlomycin reduced feed DM/unit gain by 0.22 and 0.20, respectively, relative to control groups.

Tylosin is an effective antibiotic for prevention of liver abscesses. Cattle fed no tylosin, including those fed monensin, laidlomycin or lasalocid, had an incidence of liver abscesses close to 30%, yet only 10% of cattle fed tylosin alone or in combination with monensin had liver abscesses (DiCostanzo et al., 1996); a reduction of 65%. Similarly, a recent summary of 40 studies demonstrated that cattle fed tylosin had liver abscess incidence 73% lower than that of cattle not fed tylosin (Laudert and Vogel, 2008). Although not as effective as tylosin, chlortetracycline reduced liver abscess incidence 43% in a recent summary of data by Zoetis.

Because 90% feedlots surveyed recently (USDA NAHMS, 2013) reported using ionophores, productivity of the modern feedlot is dependent on these molecules to the extent of their impact on performance and health of cattle. Further, field inclusion of these molecules became second-nature to the feed and drug manufacturing industry servicing the feedlots in the US and the world. Storage type, and warehouse capacity, product transfers between warehouse, mixing and user facilities, suspension of dry or liquid supplements or direct inclusion in finished diets and the network necessary to support provision of these molecules to an industry with a one-time capacity of 13 million cattle are important considerations when evaluating alternative feed additives in support or in substitution for conventional FDA approved ionophores and antibiotics. Inclusion rate alone may become a limiting factor for alternative feed additives that are required at more than 1 g/hd daily. For example, if one would consider full substitution of monensin with a product that is required at 1 g/hd daily, production, storage and transfer required by the industry would increase 3-fold! The authors can only imagine the public outrage; this time it would be aimed at the projected carbon footprint of the substitute feed additive.

Table 2. Proposed "ideal" traits for eubiotic feed additives to substitute or supplement ionophore and liver abscess preventive antibiotics

Performance indicator	Improvement over control	
	Minimum	Optimum
ADG	0%	3%
DMI	0%	-3%
Feed DM/unit gain	-2%	-4%
Liver abscess incidence	-45%	-75%

Other characteristics
Clear indications for storage and use
Dry feed delivery
Easy flow
Impervious to environmental conditions
Liquid feed delivery
Long mixed-in shelf-life
Long shelf-life
Low inclusion
Low or no associative effects with feed ingredients
Micro-ingredient delivery
Regulatory oversight
Small particle size

Eubiotics: Evidence of Effects on Performance

As indicated above, a variety of fermentation products and DFM may be considered eubiotics. Proportion of cattle fed a probiotic increased to 54% from 17% in 1994 amongst feedlots surveyed recently (USDA NAHMS, 2013). In that survey, a probiotic was defined as live organisms that, when administered orally to establish in the digestive tract, are believed to be favorable to animal health. Given findings by USDA NAHMS (2013) feedlot study, at any given time, there is a chance 45% of the cattle in US feedlots are receiving both an ionophore and a probiotic; yet, all DFM and fermentation products currently for sale in the US have no performance or health claims. Therefore, a review of their effect on performance is in order.

Several authors have performed excellent reviews of effects of feeding DFM and/or fermentation products on performance and health of feedlot cattle (Krehbiel et al., 2003; Brown and Nagaraja, 2009; Jennings, and Wagner, 2014; Schoonmaker, 2015; Wagner et al., 2016). This contribution aims at evaluating the evidence of effects of DFM and fermentation products on feedlot performance through the use of meta-analysis methods. This approach was used to attempt a comparison while adjusting for inherent variables such as initial BW, energy concentration of the diet, rate of fermentation of grain or co-products in the diet, location, etc. The reader is encouraged to view results of this meta-analysis as an additional installment in the long and continuous process of evaluating effects of alternative feed additives on feedlot performance.

In this section, eubiotic (DFM, fermentation product or combination) is referred to as the alternative feed additive program, added or not, to feeding an ionophore. A dataset derived from 35 manuscripts containing 126 means for treatments comparing corn- or barley-based control diet containing an ionophore with diets with or without a eubiotic or no ionophore and a eubiotic (feed additive program) in finishing beef cattle experiments was subjected to a meta-analysis to determine effects of eubiotics and ionophores on feedlot performance. Given the large choice and brand of DFM or fermentation products available and the relatively small number of studies that represent each a combination of brand and product, this meta-analysis was restricted to inclusion or not of DFM or fermentation product without regard to specific product. Products based on bacterial cultures made up the majority of this dataset. The reader is referred to Wagner et al. (2016) for a comprehensive review on the fermentation product, yeast culture, produced by Diamond V Mills (Diamond V, Cedar Rapids, IA). Table 3 lists descriptive statistics for the three feed additive programs.

Table 3. Descriptive statistics for meta-analysis data

Variable	n	Mean	SD	Min	Max
			Ionophore		
In BW, lb	39	789	114	485	1037
DMI, lb	39	20.95	3.10	15.48	28.40
ADG	39	3.43	0.63	2.19	4.98
GTF	39	0.165	0.026	0.110	0.217
FTG	39	6.05	0.97	9.09	4.61
Out BW, lb	39	1231	133	906	1468
HCW, lb	37	770	102	532	934
Dressing, %	30	61.4	3.0	54.1	64.6
			Eubiotic, no ionophore or antibiotic		
In BW, lb	29	790	91	648	921
DMI, lb	29	20.81	1.40	18.08	24.45
ADG	29	3.07	0.49	2.17	3.77
GTF	29	0.148	0.028	0.105	0.209
FTG	29	6.74	1.28	9.52	4.78
Out BW, lb	29	1131	147	889	1467
HCW, lb	25	683	120	516	932
Dressing, %	23	58.8	3.9	52.1	63.7
			Ionophore plus eubiotic		
In BW, lb	58	773	151	82	1052
DMI, lb	58	21.21	3.30	15.50	28.40
ADG	58	3.63	0.53	2.60	4.96
GTF	58	0.174	0.026	0.130	0.246
FTG	58	5.76	0.85	7.69	4.07
Out BW, lb	58	1258	126	579	1450
HCW, lb	57	792	69	539	900
Dressing, %	47	62.1	1.8	57.1	64.5

Using a mixed model approach supported by random effects of treatment within experiment, effects of feed additive program (ionophore, ionophore and eubiotic or no ionophore and eubiotic) on DMI, ADG, feed conversion (analyzed as gain per unit feed DM), final and carcass weight and dressing percentage were modeled. Covariates studied included sex, expected rate of grain or co-product fermentation (e.g., whole corn was classified as slow while steam-flaked corn was classified as fast) and initial BW. Interactive terms were tested between system and grain or co-product fermentation rate.

Results of meta-analysis on effects of feed additive program on feedlot performance are listed in Table 4. Feeding an ionophore with or without a eubiotic resulted in greater ($P < 01$) feed conversion than feeding a eubiotic with no ionophore (Table 4). No differences in feed conversion were observed between cattle fed an ionophore with or without a eubiotic (Table 4). Neither final BW nor dressing percentage were affected ($P > 0.13$) by feed additive system (Table 4). Yet, cattle fed an ionophore with or without a eubiotic had heavier ($P < 0.01$) carcasses (Table 4).

Table 4. Least square means for effects of feed additive program during the finishing phase on feed conversion efficiency, final BW, hot carcass weight and dressing percentage

			Eubiotic		
Item	Ionophore	No ionophore	Ionophore	SE	P-value
GTF	0.168 [a]	0.144 [b]	0.177 [a]	0.007	0.008
FTG	5.96	6.94	5.65		
Out BW, lb	1275	1228	1300	36.3	0.133
HCW, lb	732 [a]	679 [b]	739 [a]	35.9	0.003
Dressing, %	59.0	58.3	58.9	0.87	0.359

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

Interactive effect of feed additive program and grain or co-product fermentation rate on DMI and ADG were revealed ($P < 0.06$; Table 5). Fermentation rate had no effect ($P > 0.15$) on DMI of cattle fed an ionophore with no eubiotic; yet, ionophore-fed cattle administered a eubiotic in a slow-fermentation grain or co-product consumed more DM than those fed a fast-fermentation grain or co-product (Table 5). An opposite effect occurred in cattle fed no ionophore (Table 5): cattle fed diets containing fast-fermenting grain or co-products consumed more ($P < 0.05$) DM.

Feeding a fast fermentation grain or co-product in the diet of cattle supplemented with an ionophore or those only given a eubiotic resulted in faster ($P < 0.05$) rate of gain (Table 5). Given a eubiotic in addition to an ionophore prevented this difference in rate of gain (Table 5).

From these results, it is apparent that feeding a eubiotic in an ionophore-supplemented diet may help support DMI in diets consisting of slow-fermentation grains and co-products. Various authors have suggested a DMI-enhancing effect of several DFM and fermentation products. In their recent review, Wagner et al. (2016) observed that cattle fed yeast culture consumed more DM.

Table 5. Interactive least square means for effects of feed additive program during the finishing phase on DMI and ADG

	Ionophore		Eubiotic					
			No ionophore		Ionophore			
	Fast	Slow	Fast	Slow	Fast	Slow	SE	P-value
DMI, lb/d[a]	20.14 bc	21.21 bcd	21.79 e	19.96 b	20.42 bc	23.09 f	0.564	0.0002
ADG, lb[a]	3.51 de	2.97 bc	3.27 cd	2.67 b	3.74 e	3.76 e	0.178	0.0586

[a] Superscript row: means underlined by different superscripts differ ($P < 0.05$).

Interestingly, intake by cattle fed no ionophore responded positively (and opposite to the trend observed in those fed an ionophore only or those fed an ionophore and a eubiotic) to diets containing fast-fermenting grains or co-products. Although this is a trend in the correct direction, especially given that rate of gain was also greater for cattle fed a eubiotic with no ionophore, greater DMI with diets containing fasting fermenting ingredients may require greater observation by feedlot managers and nutritionists. Also, differences in rate of gain resulting from feeding fast-fermenting grains or co-products were not apparent when an ionophore was fed in combination with a eubiotic. This should help retain feed conversion efficiency in cattle fed slow-fermenting grains or co-products.

Mechanism of Action

Yeast Several excellent reviews and original papers have contributed to our understanding of the mechanisms of action of yeasts. In a recent meta-analysis with lactating dairy cows, yeast supplementation maintained greater ruminal pH, particularly when dairy cows were fed greater proportions of concentrate or at greater DMI (Desnoyes et al., 2009). Similarly, when rumen-cannulated sheep were adapted to high-grain diets, sheep supplemented with yeast responded with greater ruminal pH (Chaucheyras-Durand and Fonty, 2006). Greater ruminal pH likely reflects lower concentration of lactic acid (Desnoyes et al., 2009).

In feedlot cattle, lower ruminal pH should translate to a healthier rumen environment and improved overall ruminal fermentation. Vyas et al. (2014) observed that in beef heifers supplemented either with dry active or dry killed yeast, minimum and mean ruminal pH was greater. In addition, heifers supplemented with yeast, regardless of whether it was active or killed, maintained ruminal pH above 5.6 for 5.8 for longer periods daily. Starch digestibility tended to be greater for heifers supplemented with active or killed yeast. In the study of Vyas et al. (2014), no effects of active or killed yeast were observed on VFA profile or concentrations of lactate. However, concentrations of *Ruminococcus flavefaciens*, a cellulolytic bacteria, were greater in ruminal fluid of heifers fed the dry active yeast. In this regard, Desnoyes et al. (2009) reported that NDF digestion was greater in dairy cows fed dry active yeast; this effect led to greater OM digestibility in cows fed dry active yeast. Using 16s rRNA gene-based clustering, Pinloche et al. (2013) demonstrated in dairy cows that rumen bacterial populations shifted to the

fibrolytic group (*Fibrobacter* and *Ruminococcus*) and lactate-utilizing bacteria (*Megasphaera* and *Selenomonas*) in the cows that were supplemented with yeast.

Although evidence for effects of yeast on bacterial populations and resulting impact on ruminal pH and digestibility of fiber in the rumen are readily drawn from the literature, there is a lack of consistent effects on performance of feedlot cattle. Whether differences in the experimental model whence results were derived (dairy cattle fed high forage diets at high intakes) or other factors prevent a consistent response to yeast feeding is not clear from the present body of evidence.

Yeast fermentation product (YFP). The main mechanism of action resulting from feeding YFP to ruminants is derived from the presence of co-factors or prebiotics released or stimulated when yeast fermentation products are fed. Digestibility of OM and CP was reported to be greater when continuous culture samples of rumen fluid dosed with a YFP were evaluated (Yoon and Stern, 1996). Similarly, at DMI below 57 lb, lactating dairy cows fed YFP had greater starch digestion rate; at DMI above this threshold actually was negatively affected (Allen and Ying, 2012). Passage rate of starch from the rumen was not affected by treatment (mean = 24.3%/h). In vivo observations of YFP effects on DM or other nutrient digestibility in beef cattle have been inconclusive. Effects of YFP on ruminal microbial populations, fermentation end products, pH or digestibility may be affected by type and concentration of carbohydrates, mineral elements and other nutrients recovered in the fermentation media; thus, YFP effects may be highly dependent on the fermentation process and consistency thereof.

Enzyme preparations Similar to products derived from YFP, enzyme preparations are dependent on the manufacturing process to produce it. Therefore, results obtained when testing a proprietary product may not readily replicate due to factors beyond inherent ruminal environment, diet, intake, stage of production, etc. However, there is indication that enzymes may mediate attachment of microbes to plant fiber ; yet, Schoonmaker (2015) pointed out that this effect may be exaggerated if excessive enzyme is fed thereby resulting in competitive exclusion with cellulolytic bacteria.

Bacteria preparations Observations of the impact of bacterial DFM on growth performance in growing and finishing steers have been inconsistent and oftentimes transient, being observed early in the feeding period but not differing from controls over the duration of feeding. Similarly, the body of research on the effects of bacterial DFM on rumen fermentation has also been inconsistent and contradictory; likely, this inconsistency can be explained, at least in part, as a function of the variation of strain and dosage of DFM provided between studies. Greater agreement between researchers has been observed in the areas of rumen and total tract digestibility, which is not affected or diminished by DFM provision, and fecal pathogen reduction.

Researchers have explored the impact of bacterial DFM on the ruminal environment with varying results. The total concentration of ruminal VFA are generally not impacted by DFM provision (Beauchemin et al., 2003; Ghorbani et al., 2002; Kenney et al., 2015a); however, shifts in VFA profiles have been observed. The combination of *Propionibacterium* and *Enterococcus faecium* as well as the combination *L. acidophilus* and *E. faceium* have been found to increase

the molar proportion of acetate (Ghorbani et al., 2002; Kenney et al., 2015a). In contrast, an increase in the molar proportion of propionate has been observed with provision of *E. faecium* alone (Beauchemin et al., 2003). Several studies have indicated that bacterial DFM may have the potential to play a role in the prevention of ruminal acidosis through modulation of ruminal pH (Kenney et al., 2015a; Nocek et al., 2002); although conflicting evidence suggests that rumen pH may not be impacted by bacterial DFM cultures or is in fact decreased by bacterial DFM (Elam et al., 2003; Ghorbani et al., 2002; Rolfe et al., 2009). It has been postulated that provision of a bacterial DFM containing, at least in part, lactate-producing bacteria generates a tonic, low-level of lactate in the rumen which in turns stimulates growth of ruminal lactate-utilizing bacterial population and prevents the accumulation of lactic acid following consumption of a diet high in readily fermentable carbohydrates (Yang et al., 2004). This is supported by observations of Ghorbani and coworkers (2002) that *Propionibacterium* and *E. faecium* fed in combination tended to decrease blood CO_2 and decreased concentrations of lactate dehydrogenase, although rumen and blood pH were not affected. However, in vivo measures of ruminal L- and DL-lactate disappearance, independent of outflow through the reticulo-omasal orifice, and plasma L-lactate concentrations did not differ with DFM provision in response to a pulse dose of lactate (Kenney et al., 2015a). Increased rumen pH as a consequence of provision of mixed bacterial cultures containing lactate-producing bacteria does not appear to be a function of altered lactate metabolism but rather an alternative mechanism. A related theory is that DFM containing lactate-utilizing bacteria will bolster the population of rumen lactate utilizers allowing for a more robust response and faster clearance of lactate in the event of an acidotic challenge. Kung and Hession (1995) observed that inoculation with *Megasphera elsdenii* during transition from low- to high-concentrate diets prevented accumulation of lactate in vitro and a similar response has been observed in vivo by McDaniel et al. (2009) and Greening et al. (1991). Further research is necessary to identify if this response is specific to *M. elsdenii* or applicable to other lactate-utilizing bacteria as well.

Little attention has been given to determining the influence of DFM on ruminal protein digestibility and microbial crude protein synthesis and the handful of observations of the impact of DFM on rumen ammonia have been inconsistent. Beauchemin et al (2003) observed a decrease in ammonia with *E. faecium,* which may be a function of decreased protein degradability as a depression in rumen pH was also observed. In contrast, Ghorbani et al. (2002) found *Propionibacterium* increased rumen ammonia while a combination of *Propionibacterium* and *E. faecium* did not alter ammonia concentrations. A tendency for a treatment by day interaction occurred for mean daily ammonia concentration was observed in steers fed a combination of *L. acidophius* and *E. faecium*, in which the mean daily ammonia concentration remained the same in DFM treated animals from d 14 to 28, whereas in control animals ammonia concentrations increased over time (Kenney et al., 2015a). Increased ammonia concentrations at d 28 in control animals may be a function of lower mean and minimum rumen pH measures observed for these animals, resulting in a greater proportion of ammonium ions and, therefore, decreased absorption and subsequently greater accumulation in the rumen. An alternative hypothesis is that DFM provision resulted in increased bacterial utilization of ammonia. This hypothesis is supported by growth performance data that suggests that degradable intake protein (DIP) requirements are increased with provision of *L. acidophilus* and *E. faecium* (Kenney et al., 2015b). Although other work has found that measures of microbial protein synthesis and

microbial efficiency in continuous culture did not differ with provisions of *Propionibacterium* or *E. faecium* (Yang et al., 2004).

The modification of digestibility of feeds has been identified as a potential explanation for the positive performance responses, specifically increases in feed efficiency, observed in feedlot cattle; however, results have been largely not evident or negative. *In situ* DM disappearance of multiple feedstuffs (barely silage, alflalfa hay, wheat straw and barley-based high concentrate TMR) was not influenced by *Propionibacterium* or a combination of *Propionibacterium* and *E. faecium* (Ghorbani et al., 2002). Steers treated with *E. faecium* exhibited decreased *in situ* digestibility of corn, barley, and alfalfa hay (Beauchemin et al., 2003). Apparent total tract DM digestibility was not impacted by *E. faecium* or a mixed bacterial culture of lactate-producing bacteria primarily consisting of *L. acidophilus* and *E. faecium* (Beauchemin et al., 2003; Kenney et al., 2015a). Beauchemin and coworkers (2003) found that *E. faecium* had a tendency to decrease apparent total tract OM digestibility, whereas Kenney and coworkers (2015a) observed no difference in apparent total tract OM digestibility with provision of a mixed bacterial culture of lactate-producing bacteria primarily consisting of *L. acidophilus* and *E. faecium.*

Bacterial DFM cultures, specifically combinations of *L. acidophilus* and *P. freudenreichii*, have been shown to reduce fecal shedding and hide contamination of *E. coli* O157:H7 (Brashears et al., 2003; Elam et al., 2003; Peterson et al., 2007), suggesting that bacterial DFM have some capacity to affect the hind gut of ruminants, in additional to altering the rumen environment. It has been postulated that DFM may prevent against *E. coli* O157:H7 infection through the stimulation of mucus production or through competitive binding of nutritive substrates (Reid and Burton, 2002). Alternatively, DFM may competitively bind the intestinal epithelium, which has been observed in dairy calves as a consequence of provision of *L. acidophilus* along or in combination with *L. plantarum* (Abu-Tarboush et al., 1996).

DFM and Fermentation Product Shelf-Life and Interactive Feed Ingredients

Because many DFM additives are based on live micro-organisms, current users and future adapters may consider how stable these products are and how presence of other feeds ingredients, particularly fermented feeds, may impact stability and viability of these products. Depth and breadth of information available on care and handling of DFM feed additives during storage, mixing and delivery and projected shelf-life at company websites or Internet-based published information at company websites vary widely.

Yet, evidence derived from a research study pointed to several issues regarding initial and after storage concentrations of micro-organisms and impact of storage temperature on viability of micro-organisms enumerated from commercial DFM preparations. Out of five dry active yeast commercial preparations, all but one met the manufacturer's guarantee for colony-forming (cfu) units when product was received in the spring of the year (Sullivan and Bradford, 2011). In contrast, in one summer, three out of five, and in another, two out of five dry active yeast commercial preparations failed to meet the manufacturer's guarantee for cfu. This observation may emphasize the impact of environmental temperature on product stability for dry active yeast preparations as exposure to storage conditions at 104 F for even 1 mo reduced cfu/g; this reduction continued with continued exposure to 104 F for the 3 mo of the experiment (Sullivan

and Bradford, 2011). Interestingly, at 72 F and after 2 wk storage, no significant changes were observed in cfu for dry active yeast preparations mixed either with ground corn grain or a vitamin-mineral premix; yet, when exposed to 104 F and after 2 wk storage, storing the dry active yeast product with ground corn grain led to greater reductions in cfu than storing it with the premix (Sullivan and Bradford, 2011). Given these results, authors promptly pointed out that perhaps differences in delivery dates, storage conditions and premix ingredients may explain variability in lactation cow performance results with inclusion of dry active yeast products. Yet, to our knowledge, this is the only study of its kind published either as a dissertation or journal article for the industry to understand influence of environmental conditions on DFM shelf-life and stability.

Another interactive factor often cited anecdotally for effecting response by dairy or beef cattle to supplementation with DFM is the presence of yeasts in certain feed ingredients, particularly fermented feeds. Researchers in Delaware identified several strains of yeasts in corn silage and high moisture corn (Santos et al., 2014). Yeast species found in greatest concentrations in high moisture corn were *Issatchenkia orientalis* and *Pichia anomala* while *Candida ethanolica* and *bulderi* were most common in corn silage. In addition to being lactate-utilizers, thereby leading to aerobic spoilage of fermented feeds if permitted to multiply extensively, in vitro culture tubes treated with increasing concentrations *of I. orientalis* responded with lower pH, greater VFA concentration and lower NDF digestibility (Santos et al., 2014). Thus, although the sentiment that resident yeast populations may interact with feed additive yeasts or yeast cultures may not be unfounded in spite of the fact that neither this study nor any other one has further tested this hypothesis.

Novel Strategies

Passive immunization Passive immunization against certain rumen microbes is perhaps the most novel and least attempted method of rumen manipulation. Polyclonal antibodies derived from injections of ruminal bacteria or lipopolysaccharide preparations into laying hens presented promise as tools to manipulate rumen fermentation and feedlot performance.

Perhaps the thought process that an orally delivered immunoglobulin will be rapidly degraded in the rumen by bacterial proteases readily biases the ruminant nutritionist's mind. Yet, avian antibodies are known for their ability to remain active in spite of severe environmental challenges. These characteristics make avian antibodies suitable for dosing orally into ruminant animals. Feedlot cattle fed a 64 Mcal NEg/cwt corn grain diet dosed with an avian-derived, multivalent, polyclonal antibody against S. bovis had improved feed conversion efficiency (DiLorenzo et al., 2008). Similarly, when feeding corn-based diets containing 56 or 59 Mcal NEg/cwt, steers of *Bos indicus* breeding performed at similar feed conversion efficiencies than their counterparts fed monensin at 300 mg/hd daily. Counts of target bacteria were reduced transitorily (DiLorenzo et al., 2008) or during the sampling period (DiLorenzo et al., 2006) while ruminal NH3-N was decreased transitorily (DiLorenzo et al., 2008). Counts of *F. necrophorum* and liver abscess scores were lower for cattle fed a polyclonal antibody preparation against *F. necrophorum* (DiLorenzo et al., 2006; DiLorenzo et al., 2008); cattle were fed no tylosin.

A trend for increased ruminal pH was reported when a multivalent polyclonal antibody preparation was used which contained antibodies against *S. bovis* amongst other bacteria (Marino et al., 2011). Evidence from trends or numerically lower rumenitis scores in cattle fed multivalent polyclonal antibody preparations indicated that effects of increased ruminal pH may also have occurred during the entire feeding period in other studies (Pacheco et al., 2012 and Millen et al., 2015). Similarly, pre-prandial ruminal pH readings in heifers fed a multivalent polyclonal antibody preparation against *S. bovis* were greater 3 out of 4 d following an aggressive 4-d concentrate feeding step-up to feeding 28 lb/hd daily ground corn- and ground barley-based diet from 5.5 lb/hd daily (Blanch et al., 2009). In this study, heifers fed polyclonal antibody preparations against *S. bovis* also had greater ruminal VFA concentrations (Blanch et al., 2009).

The aforementioned studies were used to report on the initial forays into utilization of avian-derived polyclonal antibodies against ruminal bacteria on ruminal fermentation and feedlot performance. However, the potential to use this powerful antibody production technique to produce antibodies against specific bacterial constituents or enzymes such as lipopolysaccharides exists. Results from a recent commercial study in a large dairy in Florida highlight this impact. Cows fed a polyclonal antibody preparation against gram negative LPS produced more milk during a 98-d experimental period and more energy-corrected milk than those fed no antibody preparation (Ibarbia et al., 2014).

Next generation products Improvements in our understanding of the microbiome and its interactions with the host are leading progress in development of new and improved alternatives. Recently, a *Saccharomyces cerevisiae* fermentation product (NaturSafe™, Diamond V, Cedar Rapids, IA) was tested (at 18 g/hd daily) in a research feedlot in central Kansas for its impact on feedlot performance, liver abscesses and pathogen load and prevalence against a positive control group based on feeding monensin and tylosin and a DFM commonly used in the feedlot. Diets were formulated to contain steam-flaked corn (66% of diet DM) and wet distillers grains (18% of diet DM) with 2.9% tallow inclusion and were fed for an average of 136 d. Cattle fed NaturSafe tended ($P = 0.09$) to consume 0.3 lb more DM/hd daily than those fed the positive control. There were no differences ($P > 0.20$) in carcass-adjusted gain or feed conversion efficiency between the two groups. Neither were there differences between treatment groups for carcass characteristics ($P > 0.14$) or measures of morbidity or mortality ($P > 0.18$). The number of condemned livers was similar ($P = 0.11$) for both groups (19.3% vs 14.5%, respectively, for the positive control or prototype DFM groups). Incidence of A- liver abscess scores was significantly less ($P < 0.02$) for the NaturSafe group. Load and prevalence of both *E. coli* O157:H7 and *Salmonella* were lower ($P < 0.05$) in fecal samples and in lymph nodes (*Salmonella*; $P < 0.02$) from cattle fed NaturSafe (Carlson, 2016). Invasiveness of tissue culture cells by *Salmonella* isolated from fecal swabs and lymph nodes was less ($P < 0.03$) in cattle fed NaturSafe (68%% vs 66%), indicative of decreased virulence. This was also evidenced by lower ($P < 0.02$) expression of an invasiveness gene, *hilA*, when measured in samples from fecal swabs and lymph nodes (Carlson, 2016). Prevalences of *Salmonella* isolates from fecal swabs or lymph nodes that were resistant to florfenicol, ceftiofur, and enrofloxacin were lower in NaturSafe cattle by 17% to 100% (fecal swabs; $P < 0.09$) or 42% to 75% (lymph nodes; $P < 0.04$; Carlson, 2016).

Summary

Clear signals from consumers are driving decisions by the livestock industry to explore and implement feed additive programs that, currently, may support existing ionophore- and antibiotic-based feed additives. However, there is a perception that, someday, alternatives to these products may be the only option to support livestock production.

The beef industry is no exception: currently more cattle on feed are fed a probiotic and fewer feedlots are using ionophores. Given the inconclusive response by cattle, particularly feedlot cattle, and the fact that DFM and fermentation products are not FDA-regulated feed additives, there is a need to continue to evaluate feedlot cattle response to DFM and fermentation products, which collectively could be categorized as eubiotics.

A meta-analysis of existing data regarding effects of eubiotics on feedlot performance revealed that cattle fed ionophores with or without a eubiotic were more efficient at converting feed DM to gain than cattle fed no ionophore and a eubiotic. Interactions between expected rate of grain or co-product fermentation in the diet and feed additive program demonstrated that feeding a eubiotic and ionophores in a diet containing slow-fermenting grains or grain co-products promoted DMI at values greater than those observed for cattle fed ionophores with no eubiotic. This effect translated to greater gains by cattle fed slow-fermenting grain or grain co-products and ionophores with a eubiotic, which were not different than for cattle fast-fermenting grain or grain co-products with a eubiotic. Theoretically, this observation should lead to retention of feed conversion efficiency for cattle fed a eubiotic and an ionophore regardless of rate of fermentation of dietary grains or grain co-products.

Overall, there is evidence of the beneficial effects of feeding DFM or fermentation products on performance of cattle. However, inconsistent responses may arise from a variety of inherent factors such as dietary ingredients, ruminal environment of host animal, intake, fiber and/or starch content, length of feeding period and even feedlot management. However, there is sufficient evidence from the literature that product stability and product quality control may be compromised by environmental and premix ingredient factors. Lack of knowledge (proprietary or public) may be hindering response by products that may hold promise as a supplemental additive or substitute to conventional feed additive programs. Although regulatory oversight is not the solution for everything, industry oversight may be the least onerous step in establishing optimum production and application practices that ensure proper and effective utilization of eubiotic products.

Further, characteristics of a feed additive beyond its efficacy may be the greatest obstacle limiting its application in the future. Several were listed in this review, but one, dose size, may actually have serious implications. Conventional feed additive programs are based on low inclusion doses (under 400 mg/hd daily). Supplemental or substitute feed additives currently available are required at greater doses. Larger inclusion doses may require 3- to 90-fold greater production, storage, transfer and delivery capacity by the industry.

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Diamond V®

YEAST CULTURE

WHY THE INTERSECTION OF MICROBIOLOGY AND NEUROBIOLOGY MATTERS TO ANIMAL NUTRITION

Mark Lyte, Ph.D., M.S., MT(ASCP)
Iowa State University, College of Veterinary Medicine

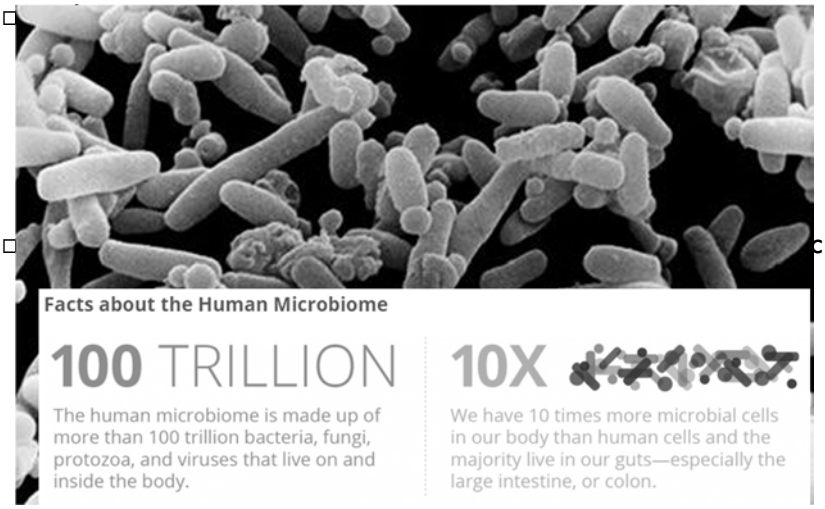
April 14, 2016 | Plains Nutrition Council Spring Conference

Structure of talk

- Introduction of bacteria as neuroendocrine organisms.
  - What prompted creation of field
    - Evolutionary vantage point
- What does this mean for understanding the complex interactions between host and microbiota that may influence animal health.
  - Consideration of microbiota from neuroendocrine vantage point allows introduction of paradigms to understand and develop new therapeutic approaches including nutrition and probiotics.
  - Concept of neuroendocrine-bacterial interactions has been termed ***Microbial Endocrinology***.
- Understanding the potential of the microbiome: ***separating hype from reality***.

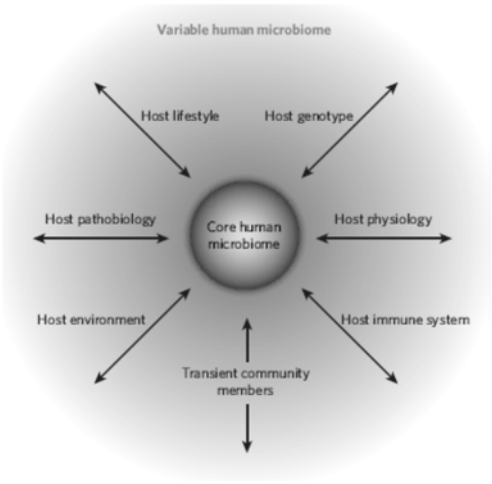
Why discussion of "hype from reality" matters…

The microbiota…



Source: http://www.serestherapeutics.com/our-science/microbiome-101

Ways by which the microbiota is perceived to interact with the host…

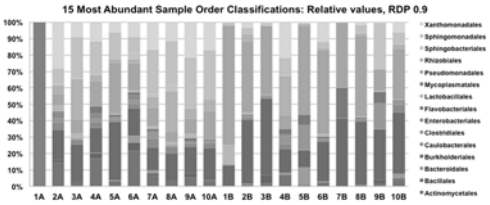


PJ Turnbaugh et al. *Nature* 2007;449:804-100

Why the emergence?

- Due to technology
  - Prior we could only "see" what we could culture
    - Preponderance of work on pathogens

Isolation of bacterial DNA from fecal (human, rodent) or gut (rodent)

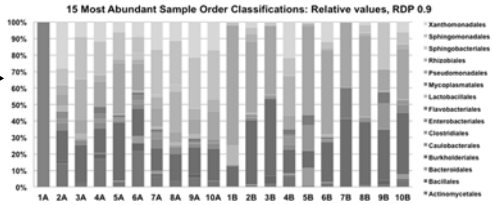


Scientific American. May 2012.

Why the emergence?

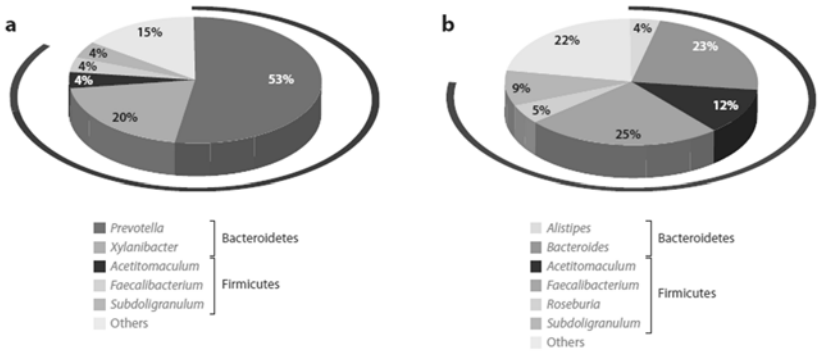
- Due to technology
  - Prior we could only "see" what we could culture
    - Preponderance of work on pathogens

CAVEAT: Technology is rapidly changing which means what is there with one technology platform may not be there with another.



Scientific American. May 2012.

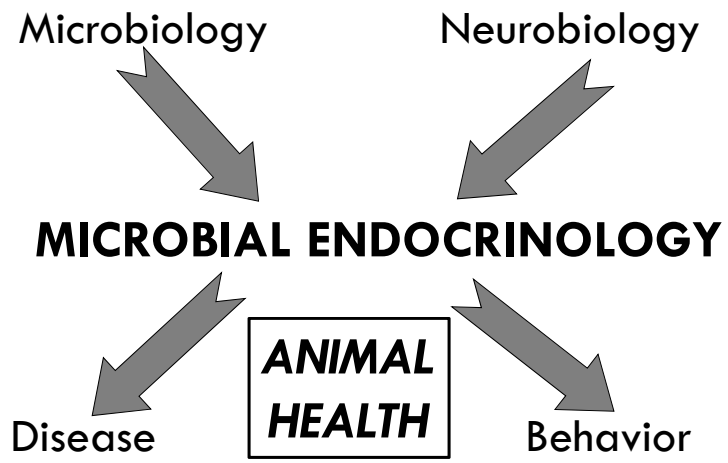
Microbiome is highly variable



African children **Italian children**

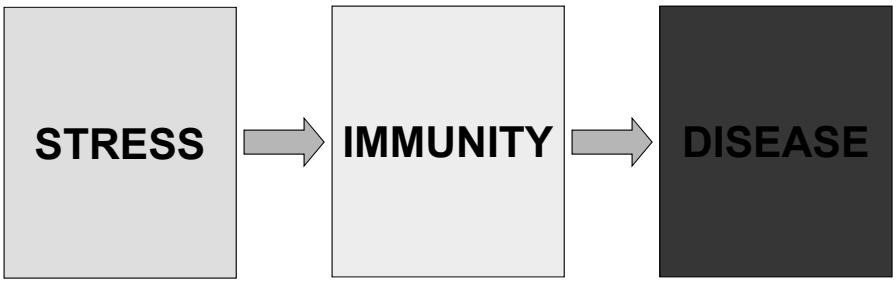
Pflughoeft KJ, Versalovic J. 2012.
Annu. Rev. Pathol. Mech. Dis. 7:99–122

Microbial endocrinology defined



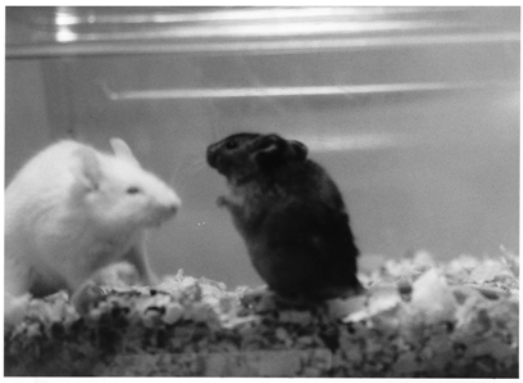
Evolution as a theme throughout

Stress-immune interactions



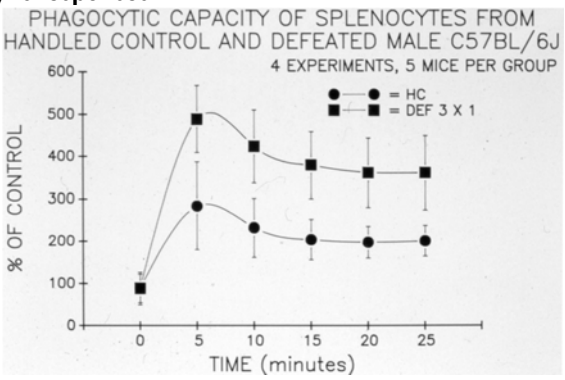
IS THIS THE COMPLETE STORY?

Social conflict stress



Immune responses of intruder mice:

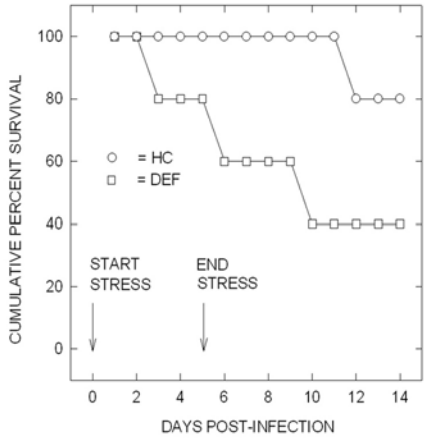
- ***In vitro* response to lymphocyte mitogens and *in vivo* anti-KLH antibody formation:**
  - **No changes between groups. Different mouse strains.**
- **Phagocytic responses:**



Lyte *et al.*, Clin. Immunol. Immunopath. 57:137-47, 1990

Does stress protect from infection?

- **Social conflict stress and then gave orally the common food pathogen *Y. enterocolitica*.**



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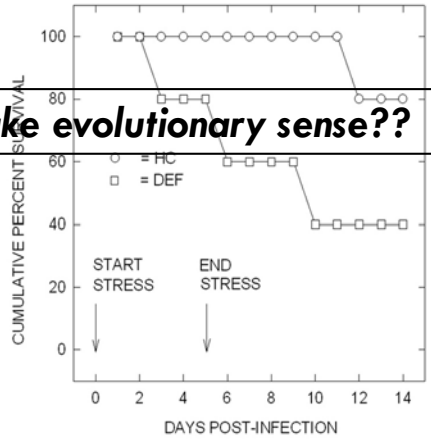
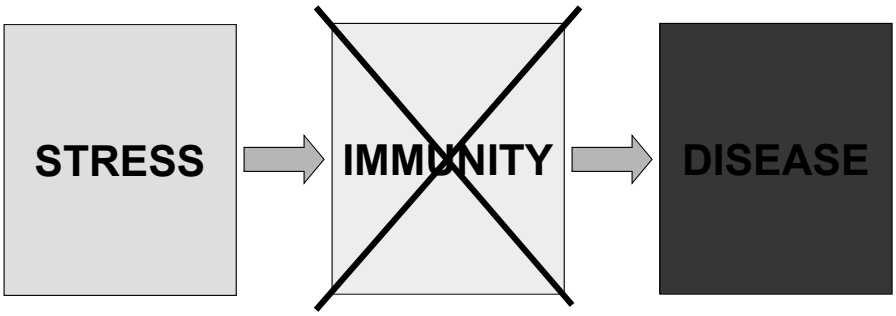


Does this make evolutionary sense?? For whom??

Stress-immune interactions - reconsidered



Whose survival are we talking about? Are microorganisms neurochemical responsive organisms?

Presence of neurochemicals in food:

- Bananas
  - 700 µg/g dopamine and 70 µg/g NE
  - Division between peel and pulp
    - Waalkes *et al.*, Science 127:648, 1958.
- Tribal pulses
  - 8 g of L-Dopa per 100 g of flour
  - Resistant to destruction by autoclaving and boiling
- Other common foodstuffs
  - Tomatoes - dopamine, tyramine
    - Use of psychoactive drugs and MAOI restrictive diets
  - Cheese - tyramine

Ubiquity of neurochemicals in food chain:

Potato plants contains the catecholamines norepinephrine and dopamine

- Szoba *et al.*, Phytochemistry, 58:315-20, 2001

And for ruminants, silage is a source of high tyramine levels

- Macpherson, J Sci Food Agric 13:29-32, 1962

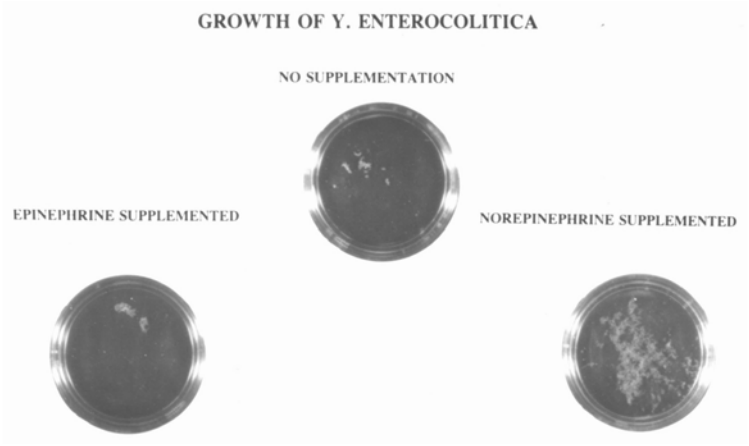
Presence of neurochemicals in the microbial world:

- Bacteria
  - Insulin-like material - present in all strains examined
  - GABA – Clinical bacterial pathogens
  - Somatostatin - *Bacillus subtilis*
  - Catecholamines – *E. coli*
  - Specific receptors have been demonstrated - 100% homology of *E. coli* EnvY gene for high affinity opioid binding site.
  - Probiotics produce neurochemicals such as GABA
  - Tryptamine – Human microbiota
- Protozoa
  - Catecholamines - *Crithidia fasciculata*, *Paramecium*
  - Serotonin - *Tetrahymena pyriformis*
- Fungi
  - Sex pheromone - Truffles (Androsterol)

Presence of neurochemicals in the microbial world:

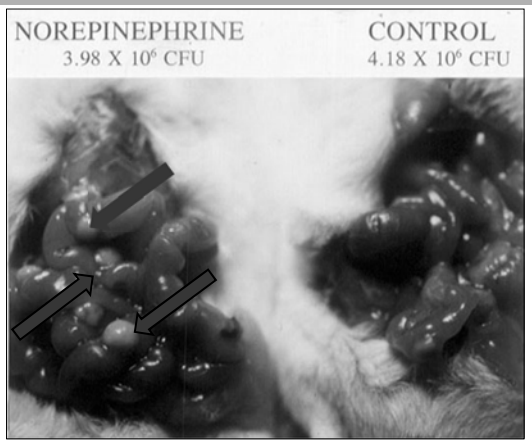
Do neurochemicals affect bacteria?

First observation: *Yersinia enterocolitia*



Lyte & Ernst, Life Sci. 50:203-12, 1992

Pre-treatment with norepinephrine increases virulence of *Y. enterocolitica*



One week post-challenge *Y. enterocolitica* pre-treated with norepinephrine 50,000X more infective.

Lyte, Microbial endocrinology (ISBN 978-1-4419-5575-3), 1-16, 2010

Common theoretical thread:

- There is an evolutionary relationship between microorganisms and host.
- Evolution of cell-cell signaling in animals may be due to late horizontal gene transfer from bacteria.
  - Iyer *et al.*, Trends in Genetics 20:292, 2004.
- Microorganisms, such as those in the gut (really everywhere), do not simply rely on traditional nutritive (energy) sources for their survival and behavior.
- Concept of direct neuroendocrine-bacterial interactions means bacteria interactive player.

Stress and animal infections

- Stress associated with infection & fecal shedding enteric pathogens such as *Salmonella enterica* & *Escherichia coli* O157:H7.
- Handling stress can modulate GI microflora & increase pathogen dissemination.
- Enteric pathogens problem for meat industries.
- Stress may also be factor in respiratory-associated infections.

Relevance of microbial endocrinology to infectious disease

Each condition possesses common set of conditions applicable to microbial endocrinology

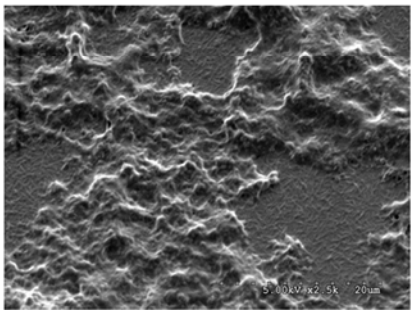
Clinical relevance of microbial endocrinology

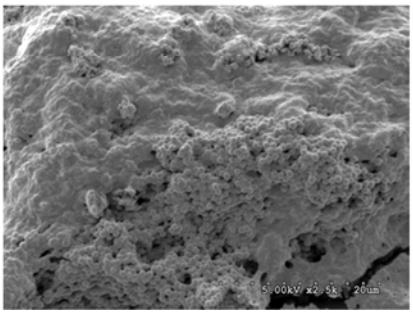
MECHANISMS OF DISEASE

Mechanisms of disease

Lancet 361:130-5, 2003

Stimulation of *Staphylococcus epidermidis* growth and biofilm formation by catecholamine inotropes

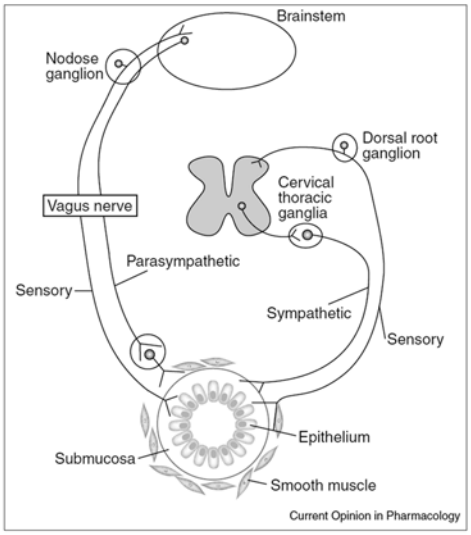




"Low hanging fruit" – Bovine respiratory diseases – causation and prevention

- What do we know about the neuroendocrine environment of the lung, especially in cattle?
- Limited studies – most concerned with stress effects
  - Adrenergic stress or catecholamine "storm"
  - Increase in catecholamine levels due to multiple conditions leads to pulmonary edema
- From clinical standpoint increases in catecholamine levels in lung lead to pulmonary dysfunction including septic shock and acute lung injury
  - Effect are *NOT* currently interpreted in terms of direct neuroendocrine-bacterial interactions
  - *Mannheimia haemolytica* - opportunist

Innervation of lung by nervous system:

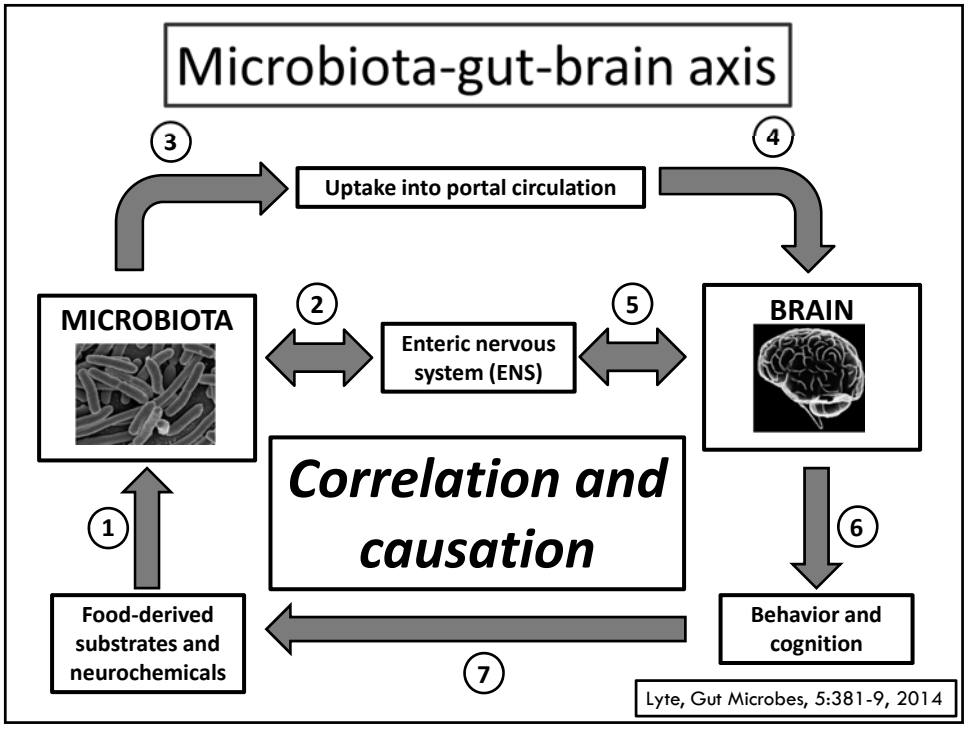


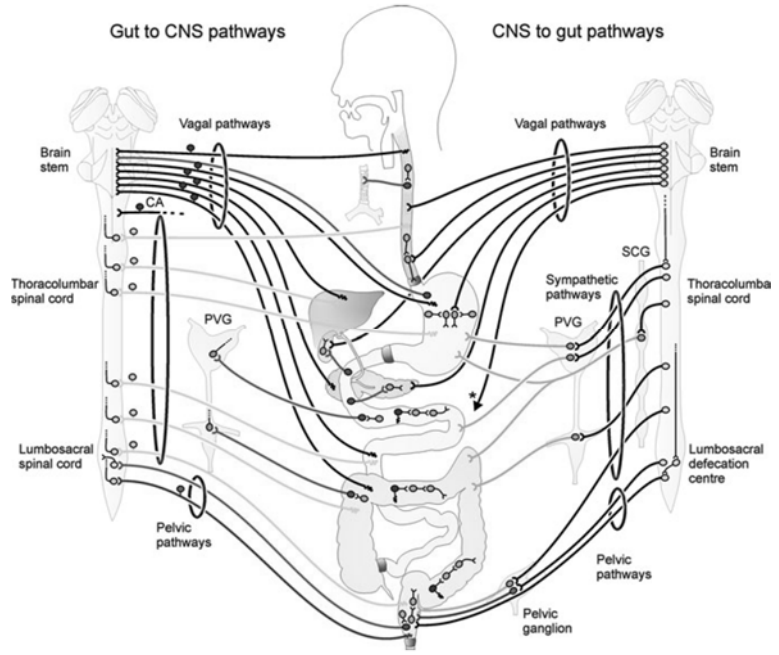
Presence of neuroendocrine hormones in the lung

- Limited studies – most concerned with stress effects
  - Adrenergic stress or catecholamine "storm"
  - Increase in catecholamine levels due to multiple conditions leads to pulmonary edema
- From clinical standpoint increases in catecholamine levels in lung lead to pulmonary dysfunction including septic shock and acute lung injury
  - Effect are *NOT* currently interpreted in terms of direct neuroendocrine-bacterial interactions

Gut – *Where neurochemicals and bacteria meet*

- Production and metabolism of norepinephrine and dopamine within mesenteric organs over 50% total body.
  - Åneman *et al.*, J. Clin. Invest. 97:1640, 1996; Eisenhofer *et al.*, Am. J. Physiol. 268:G641, 1995.
- Within lumen of GI tract physiologically relevant levels of neurochemicals:
  - Serotonin.
  - Norepinephrine and dopamine.
    - Produced by luminal bacteria
- Dietary sources:
  - Foods are a rich source of neurochemicals



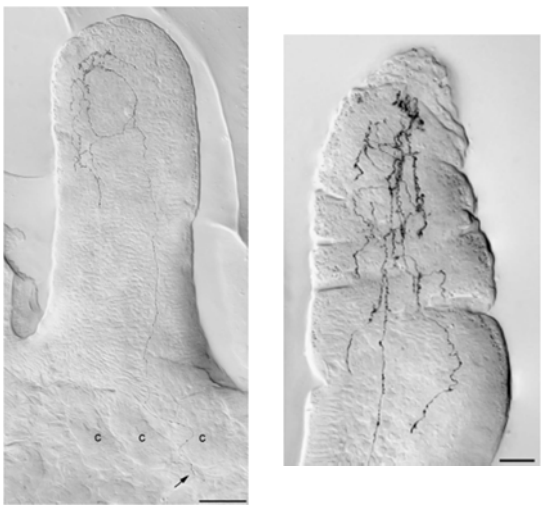


Furness *et al.*, Adv. Exp. Med. and Biol. 817: 39-72, 2014

How extensive is the innervation in the ENS where bacteria are in close proximity?

Vagal villus afferents

Question is where does information flow and *possible bi-directionality*

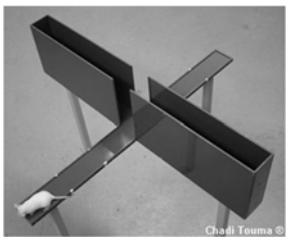


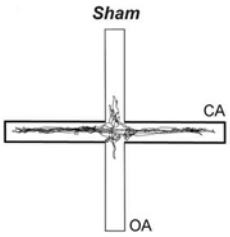
Powley *et al.* Journal of Comparative Neurology 519:644-60, 2011

Gut vagal afferents modulate behavioral responses

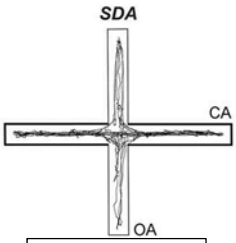
- What is consequence of this "bottom-up" information flow from gut-to-brain?
- Klarer *et al.* performed sub-diaphragmatic deafferentation
  - Klarer *et al.* Journal of Neuroscience 34:7067-76, 2014

Take home message: *"Emphasizes an important role of afferent visceral signals in the regulation of emotional behavior"* – a.k.a: *"..gut feelings"*





Anxiety-like behavior



Anxiolytic effect

Where we have come from…

- Emergence of human microbiome and what it means for behavior in a microbiota-gut-brain axis:
  - In 1911, Kellogg and use of colectomy to improve human temperament and health: *"Should the colon be sacrificed or reformed…I have labored constantly and earnestly to devise and perfect methods for changing the intestinal flora…"*
    - Kellogg, JAMA, 1911(68:1957)
  - From 1914: *"The control of man's diet is readily accomplished, but mastery over his intestinal bacterial flora is not… They are the cases that present…malaise, total lack of ambition so that every effort in life is a burden, mental depression often bordering upon melancholia…A battle royal must be fought and when this first great struggle ends in victory for the Bacillus bulgaricus it must be kept on the field of battle forever at guard…"*
    - *Stow, Medical Record Journal of Medicine and Surgery, 1914*

How far things have gone…

Panchin *et al. Biology Direct* 2014, **9**:14
http://www.biologydirect.com/content/9/1/14

Biology Direct

HYPOTHESIS Open Access

Midichlorians - the biomeme hypothesis: is there a microbial component to religious rituals?

Alexander Y Panchin[1*], Alexander I Tuzhikov[1,2] and Yuri V Panchin[1,3]

Abstract

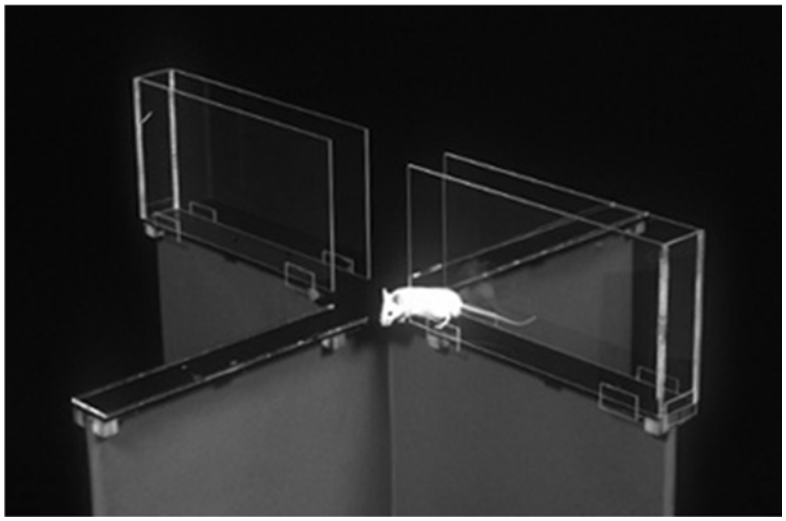
Background: Cutting edge research of human microbiome diversity has led to the development of the microbiome-gut-brain axis concept, based on the idea that gut microbes may have an impact on the behavior of their human hosts. Many examples of behavior-altering parasites are known to affect members of the animal kingdom. Some prominent examples include *Ophiocordyceps unilateralis* (fungi), *Toxoplasma gondii* (protista), *Wolbachia* (bacteria), *Glyptapanteles sp.* (arthropoda), *Spinochordodes tellinii* (nematomorpha) and *Dicrocoelium dendriticum* (flat worm). These organisms belong to a very diverse set of taxonomic groups suggesting that the phenomena of parasitic host control might be more common in nature than currently established and possibly overlooked in humans.

Presentation of the hypothesis: Some microorganisms would gain an evolutionary advantage by encouraging human hosts to perform certain rituals that favor microbial transmission. We hypothesize that certain aspects of religious behavior observed in the human society could be influenced by microbial host control and that the transmission of some religious rituals could be regarded as the simultaneous transmission of both ideas (memes) and parasitic organisms.

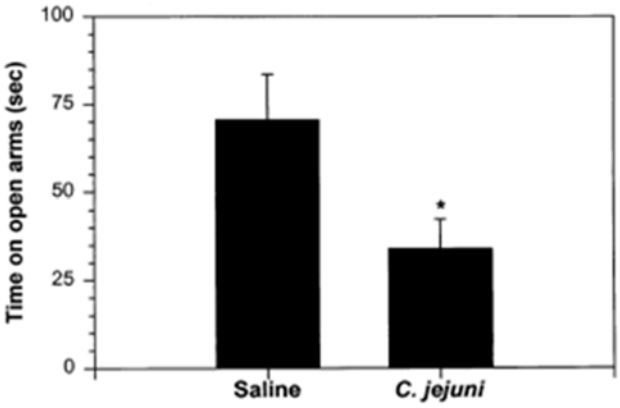
Bacteria in the gut are "seen" by the brain

- Introduction of novel bacterial species
  - Critical that bacterial species chosen does not cause overt immune response or systemic infection
  - Use of live, replicating organism instead of killed or antigen
    - *Campylobacter jejuni* – infection/diarrhea not produced
- Natural infection route
  - Per oral for C. *jejuni*
- Measure behavior
  - Apparatus used in psychopharmacology
  - Anxiety-like behavior

Elevated plus-maze:

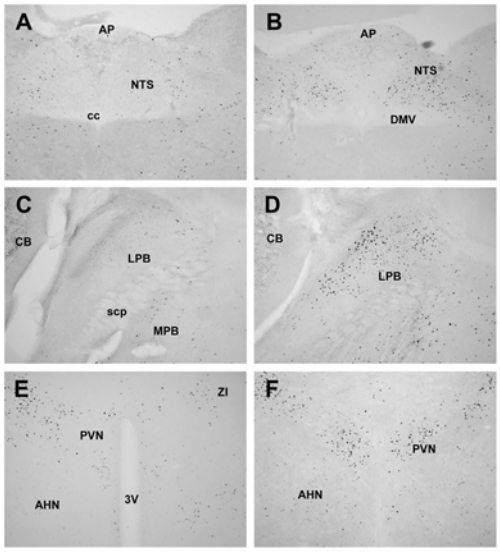


Bacteria in gut induce anxiety-like behavior:



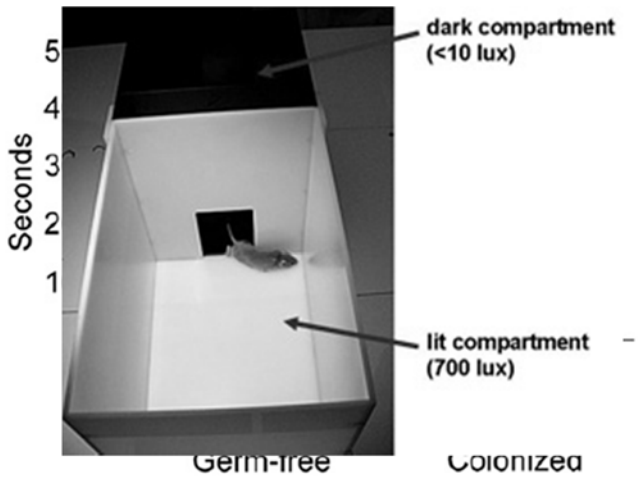
Lyte *et al.* Physiol. Behav. 65:63-8, 1998

Bacteria in gut can activate neurons in brain:



Lyte *et al.* Brain, Behav. Immun. 18:238-45, 2004

Transplant of intestinal microbiota transfers behavior:



Bercik *et al.*, Gastroenterology, 141:599-609, 2011

Through the lens of microbial endocrinology

- Neuroendocrine-bacterial interactions imply a long evolutionary pathway where mammalian hormones evolved first in bacteria.
- Evolutionary symbiosis implies that clinical conditions involving both the gut (where the bugs are) and brain (which interprets gut signals) can be viewed in a new paradigm.
- New nutritionally-based mechanisms can be identified and new therapeutic approaches, such as probiotics, formulated.

Microbial endocrinology and nutrition

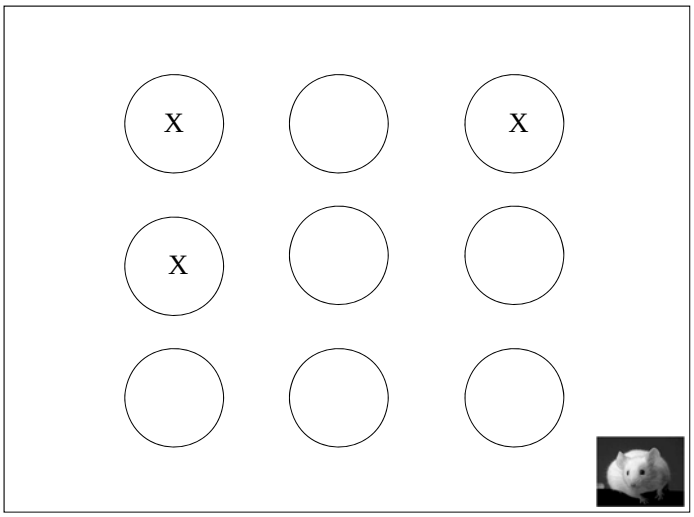
- Question being asked is whether nutrition can be used as a means to alter the microbiota and thereby influence production of neurochemicals within the gut.
- Would such an approach have consequences for the host?
- If so, a new spectrum of nutritive approaches to benefit the animal can be identified which utilize microbial endocrinology as a governing mechanism.

Experimental design

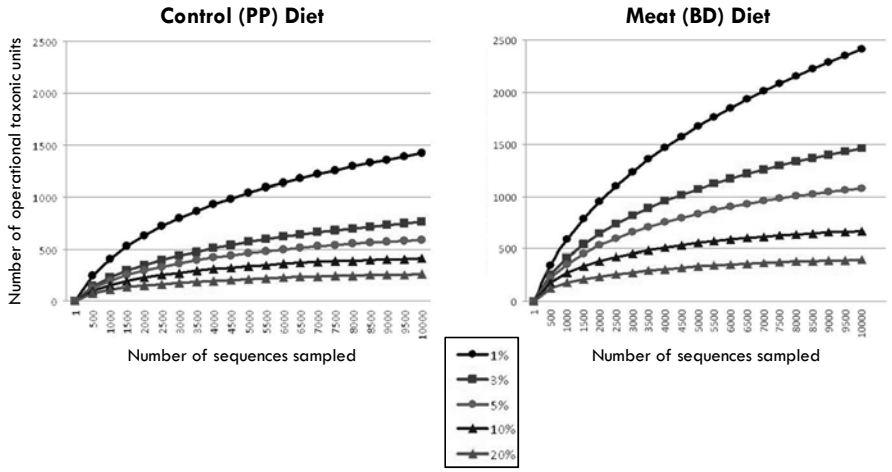
- Use of meat-based diet to alter microbial flora
  - Literature shown mice readily consume meat-based diet with consistent changes in composition of bacterial flora
    - Past literature solely culture-based
  - Effects of diet on behavior always ascribed to direct effect on neural substrates
- Feed mice meat-based diet and use pyrosequencing to examine bacterial diversity
- Measure behavior
  - Anxiety-like behavior
  - Memory and learning

CAVEAT: CORRELATIONAL STUDY – Not direct cause and effect
FIRST STEP

Hole-board design

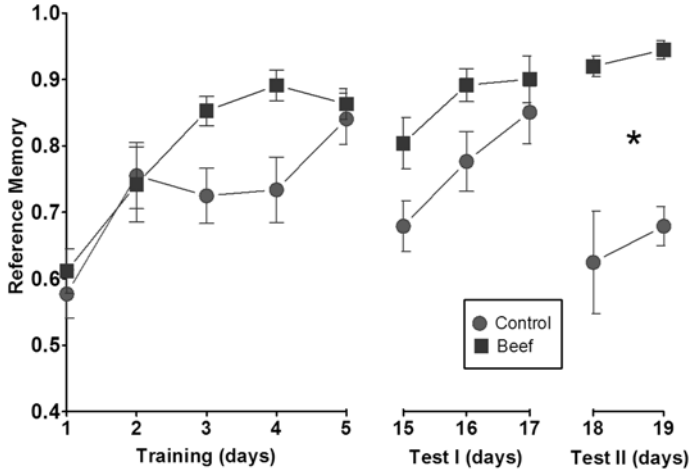


Effect of diet on bacterial diversity



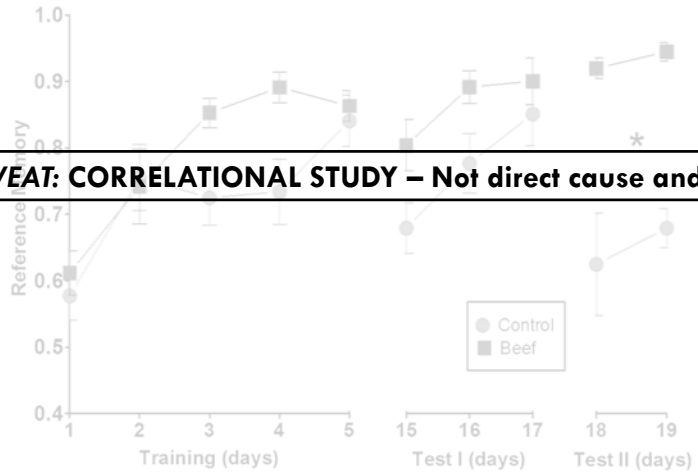
Li *et al.*, Physiology and Behavior 96:557-67, 2009

Effect of diet on reference memory



Li *et al.*, Physiology and Behavior 96:557-67, 2009

Effect of diet on reference memory



***CAVEAT:* CORRELATIONAL STUDY – Not direct cause and effect**

Li *et al.*, Physiology and Behavior 96:557-67, 2009

Microbial endocrinology and nutrition

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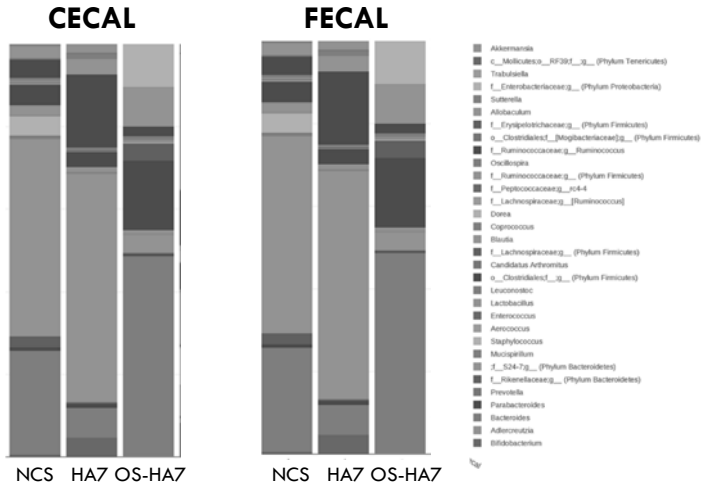
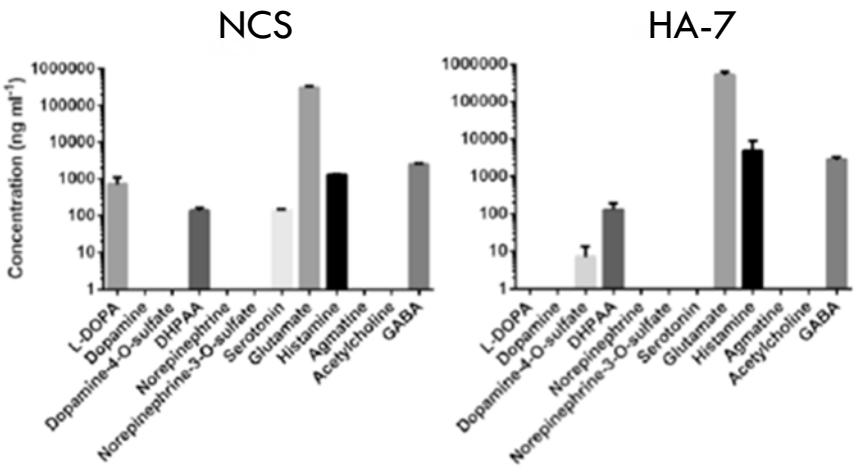
Resistant starch as dietary means to alter microbiome



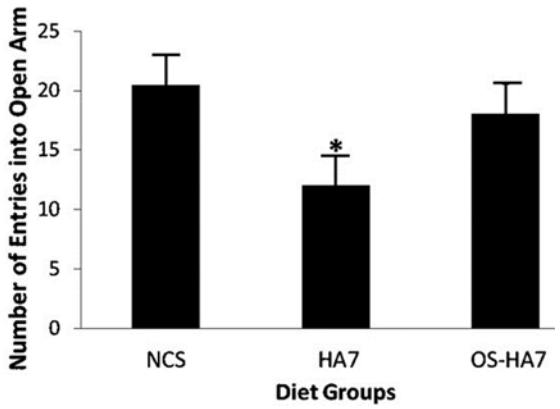
Lyte *et al*. PLoS ONE; 2016:11(1): e0146406. doi:10.1371

Detection of neurochemicals in stool



Resistant starch-induced behavioral changes

Elevated plus maze



Lyte *et al*. PLoS ONE; 2016:11(1): e0146406. doi:10.1371

Probiotics as neurochemical delivery system to influence behavior:

- Probiotics can be used to influence behavior
- Numerous studies by groups have amply shown the ability of probiotics to influence anxiety-like conditions in humans and animals, as well as other behavioral states.
- Difference is mechanism responsible for the ability of probiotics to influence behavior
  - Solely immunological mechanisms usually considered
  - ***What if considered from the lens of microbial endocrinology?***

Lyte, BioEssays, 33:574-581, 2011

What do probiotics make?

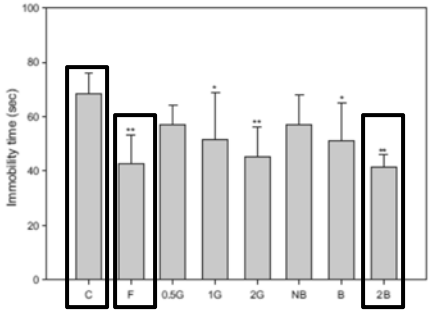
Genus	Neurochemical
Lactobacillus, Bifidobacterium	GABA
Escherichia, Bacillus, Saccharomyces	Norepinephrine
Candida, Streptococcus, Escherichia, Enterococcus	Serotonin
Bacillus, Serratia	Dopamine
Lactobacillus	Acetylcholine

Neurochemical levels produced by probiotics are physiologically relevant – often in the mg/ml level

Lyte, BioEssays, 33:574-581, 2011

So what evidence exits this approach may work?

- *Lactobacillus brevis* FPA 3709 produced high levels of GABA in black soybean milk (Ko *et al*. Process Biochem. 48:559-68, 2013)
  - Strain located after screening of 15 different fish species intestines
  - Black soybean milk made from homogenized beans
- Rats were administered GABA-rich soybean milk initially freeze-dried, homogenized and added as powder



GABA-rich soybean milk as effective as fluoxetine as antidepressant in rat forced swimming model

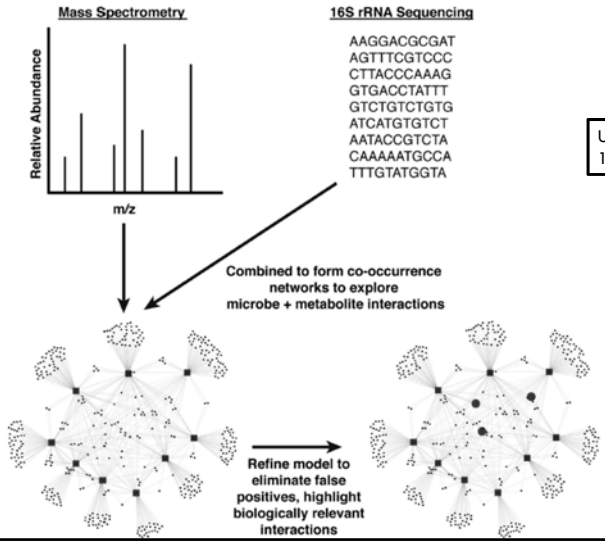
Ko *et al*. Process Biochem. 48:559-68, 2013

How would you test??

Step	Comments
Identify neurochemical of interest to be produced by probiotic based on desired physiological and/ or behavioral effect in host.	Physiological and/or behavioral measures should be readily quantifiable. Measures that are receptor-based with known antagonists readily available are preferred as can subsequently be employed at in vivo steps involving animal models.
Screen candidate probiotic in vitro for neurochemical production using robust assay to determine if neurochemical of interest as well as other neurochemicals are produced.	An example of a metabolomics-based screen is given in Table 3. More than one microbiological growth medium should be used. Preferably a medium that reflects the gut environment should also be employed.
Define kinetics (i.e. time dependent achievable intra- and extra-cellular concentrations) of neurochemical production.	Identify in vitro growth conditions which result in sustained levels of neurochemical production throughout growth period.
Obtain non-producer mutant (either through in vitro screening or site-directed mutagenesis procedure).	A mutant that does not produce the neurochemical will provide critical control for in vivo experiments.
Conduct time and dose-dependent per oral administration of neurochemical-producing probiotic in normal animals to determine ability of probiotic to produce neurochemical in vivo. Employ vehicle -only animals as control.	Measure levels of neurochemical of interest in intestinal luminal fluid and plasma. Determine time-dependent colonization of gut tissue using quantitative PCR. Perform gross pathology and immunohistopathology of relevant tissue and compare to control (vehicle only) animals.
Perform per oral administration of probiotic in an animal model which involves a neurochemical-responsive element.	Animal models of specific disease pathology or behavior are suitable candidates. Select dosage of neurochemical-secreting probiotic from prior step that is found to result in high and sustainable levels of neurochemical within the gut. If known receptor antagonists are available, give antagonist to block neurochemical-responsive element of disease or behavioral process.
Perform control experiments utilizing per oral administration of mutant (non-neurochemical-secreting) probiotic.	Quantifiable changes in animal model that are obtained by administration of neurochemical-secreting probiotic in above step should not be present (or at lower levels) with mutant strain.

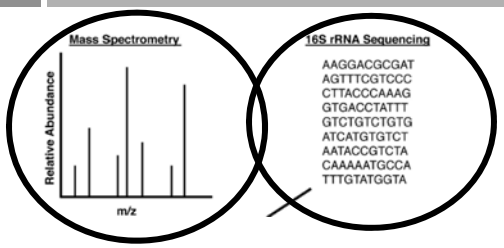
Lyte, BioEssays, 33:574-581, 2011

What we think we know…And what we ***really*** know…



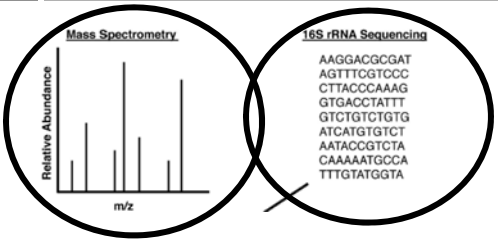
Ursell *et al.* Gastroenterology. 2014; 146(6): 1470–1476.

What we think we know…And what we ***really*** know…



- Sequencing information:
  - Issues with methodology
  - We don't really know what all the genes do
    - For *E. coli* K12: **only** 54% of gene-coding products are directly linked to a biological function.

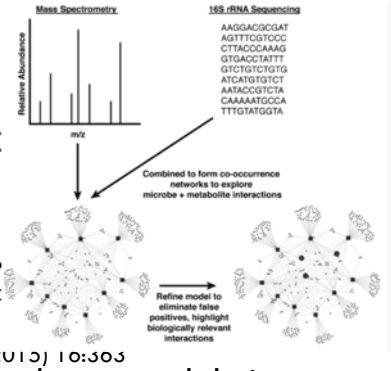
What we think we know…And what we ***really*** know…



- Metabolome:
  - In mass spec-based metabolomics studies less than 2% of peaks can be matched known compounds and only fraction can be mapped to recognized biochemical pathways.

What we think we know…And what we ***really*** know…

- So what does it say about uniting the two?
- "Computational Challenges to
  - Ursell *et al*. Gastroenterology. 2014; 146(
- Bioinformatics-based approac result with same set of data.
  - When experiments using only 11 ***know*** with programs using reference databc species were falsely predicted by the
    - Peabody *et al*. BMC Bioinformatics (2015) 16:363



- It's not as much as who are the players and their numbers, as what are the players doing
  - Otherwise known as "What are the mechanisms"
- ***BACK TO CULTUROMICS***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Pulmonary Hypertension in Finishing Cattle

J.M. Neary,[1] F.B. Garry,[2] T.N. Holt,[2] P.S. Morley,[2] R.D. Brown,[3] K.R. Stenmark,[3] R.M. Enns,[4] M.G. Thomas[4]

[1]Department of Animal and Food Sciences, Texas Tech University
[2]Department of Clinical Sciences, Colorado State University
[3]Division of Pediatric Critical Care, University of Colorado at Denver
[4]Department of Animal Sciences, Colorado State University

Summary

Right-heart failure (RHF) due to pulmonary hypertension, more commonly known as brisket disease or high altitude disease, is a complex disease that is becomingly increasing problematic for the cattle industry–regardless of altitude. The disease became known as high altitude disease because until the mid-1960s RHF was only reported at altitudes over 7,000 ft. Today, RHF is still problematic in high altitude cow-calf operations and is occurring with increasing incidence in feedlot cattle irrespective of altitude. The clinical signs are commonly mistaken for chronic pneumonia, which complicates disease diagnosis and reporting. Moreover, feedlot cattle treated for pneumonia have 2 to 3 times greater risk of developing RHF than cattle not treated. An ongoing investigation of beef cattle mortality on a feedlot at 3,000 ft. in the Texas Panhandle indicates that respiratory disease and RHF are intimately linked. Cattle with evidence of pneumonia may have actually died from RHF; however, close examination of the heart is required for an accurate diagnosis.

Introduction

One hundred years ago, two researchers from the Colorado Agricultural College, now Colorado State University, set out to investigate a strange new disease that was killing cattle in South Park, Colorado. These researchers, George Glover and Isaac Newsom, gave this new disease the name brisket disease because one of the clinical signs included swelling of the brisket (Glover and Newsom, 1915). They concluded that the disease was caused by exhaustion of the heart due to the low oxygen levels associated with high altitude exposure. The progeny of bulls originating from low-altitude were reported to be particularly susceptible to PAH, providing the first evidence for a genetic basis to the disease (Glover and Newsom, 1915). The disease also became known as ‘high altitude disease’ because, up until the 1960’s, the disease was only seen at altitudes over 7,000 ft. (Hecht et al., 1962).

Studies of the bovine lungs and pulmonary arteries, conducted in the early 1960s, revealed that a key process in the development of pulmonary hypertension was the remodeling of the pulmonary arteries (Alexander and Jensen, 1963a, b). The pulmonary arteries conduct deoxygenated blood from the right-ventricle of the heart to the lungs for re-oxygenation. In the same year, however, it was also reported that cattle with RHF have increased resistance to blood flow downstream of the pulmonary capillaries (Kuida et al., 1963). The increased resistance suggests that narrowing and remodeling of the pulmonary veins, which return the oxygenated blood to the left side of the

heart, may also contribute to the development of pulmonary hypertension. This latter finding remains to be investigated.

Differences between right heart failure (brisket disease) and other causes of heart failure

Brisket disease or RHF should not be confused with other causes of heart failure. These other causes affect specific areas of the heart:

1. **Pericarditis:** inflammation of the pericardium, the *outside* of the heart. Hardware disease (traumatic pericarditis) is a common example.
2. **Myocarditis:** inflammation of the myocardium, the *wall* of the heart. *Haemophilus somni* infection of the left ventricle is one example.
3. **Endocarditis:** inflammation of the endocardium, the *inside* lining of the heart. Bacterial colonization of the major heart valves is one example.

Brisket disease differs from the above heart diseases because, unlike the above, the disease does not involve a specific area of the heart. Rather, the entire right-heart is involved due to narrowing of downstream vessels, in the pulmonary arteries–this is technically called cor pulmonale. Importantly, on necropsy examination, the above diseases can produce similar lesions to RHF; consequently, the heart must be closely examined for other possible causes of heart failure.

What is pulmonary hypertension?

There has been no formal definition of bovine pulmonary hypertension; however, cattle with mean pulmonary arterial pressure (PAP) >49 mm Hg are considered to be at greatest risk of brisket disease (Holt and Callan, 2007). Alveolar hypoxia, or reduced oxygen tensions at the level of the gas-exchange membranes of the lung, causes pulmonary arteries to constrict (acute response) and remodel (chronic response). This increases the resistance to blood flow–just like a blocked or kinked hose pipe–and causes the blood pressure in the pulmonary arteries to rise. This increases the workload on the right-ventricle causing it to hypertrophy, or thicken, (acute response) and dilate (chronic response). The dilation of the right-ventricle indicates that blood is becoming congested in the venous system.

Incidence of right-heart failure (brisket disease)

In a recent epidemiological study, which involved 1.6 million cattle fed in 15 feedlots across North America, we found that the incidence of RHF doubled from the years 2000 to 2008 (Neary et al., 2015a). In 2012, 15 out of every 10,000 cattle entering US feedlots died of RHF (Neary et al., 2015a). A study, conducted in the mid-1970s, of 4 U.S. feedlots located at an altitude of 5,000 ft. reported the risk of CHF to be 3 cases per 10,000 cattle entering the feedlot (Jensen et al., 1976). Although direct comparisons between these two studies cannot be made, the findings do, however, suggest that the incidence of RHF has increased in the feedlot industry. Furthermore, RHF was observed in feedlots at all altitudes (Figure 1); consequently, ‘high altitude disease’ may not be an appropriate name for RHF, at least in feedlot cattle–high altitude merely increases the baseline risk.

In another study, involving 152 Angus steers, we found that mean PAP increased with age from calfhood to the late feedlot finishing phase (Neary et al., 2015b). Mean PAP increased from 4-months (39 ± 3 mm Hg; mean ± SE) to 6-months of age (42 ± 3 mm Hg) at an altitude of 7,200 ft., and from 13-months (43 ± 1 mm Hg) to 18-months of age (50 ± 1 mm Hg) at an altitude of 4,000 ft. These findings indicate that PAP may actually be greater in the feeding period at low altitude than in suckling calves located at higher altitudes. Furthermore, the increase in mean PAP through the feeding period may explain why RHF typically occurs in fed-cattle after approximately 120 days-on-feed (Neary et al., 2015a).

Nutrition and pulmonary hypertension

Unfortunately, little is known about nutritional risk factors for bovine pulmonary hypertension. It has been suggested that ruminal engorgement following feeding may be a risk factor (Jensen et al., 1976). The rationale being that forward pressure on the lungs from a distended stomach reduces lung volume resulting in rapid, shallow breathing, alveolar hypoxia, and consequently hypoxia-induced vasoconstriction of the pulmonary arteries.

Clinical signs

In many cases, brisket disease occurs undetected because the clinical signs of congestive heart failure are variable and may be confused with respiratory disease (Glover and Newsom, 1915; Malherbe et al., 2012; Neary et al., 2013). These include labored, or open-mouth, breathing, rough hair coat, glazed eyes, and reluctance to move. More specific signs of heart failure include swellings of various body regions including the brisket region (hence, brisket disease), belly, and under the jaw. The jugular vein will also become engorged with blood and, later in the disease, may show pulsations, which indicates that the major valve in the heart (tricuspid valve) is leaking.

Necropsy findings

On necropsy examination, cattle that died of RHF will have an enlarged, flabby right ventricle (the chamber of the heart closest to the head) (Figure 2). Other findings typically include,

1. Enlargement of the liver and a mottled or ‘nutmeg’ appearance when sliced,
2. Fluid accumulation in the chest and abdomen,
3. Edema (fluid accumulation) of the intestines and mesentery (membranous tissue in the abdomen),
4. Enlargement of the mesenteric lymph nodes (due to edema)
5. Fluid accumulation in the pericardial sac (membrane surrounding the heart).

Other potential causes of heart failure–previously described–must also be ruled out. Unfortunately, there is no treatment for this disease and many of the risk factors remain unknown. This is concerning for the cattle industry, particularly if the incidence of the disease continues to increase.

Pulmonary arterial pressure measurement

Unfortunately, we cannot directly determine an animal’s risk of RHF. Instead, we have to rely on pulmonary arterial pressure (PAP) measurement (Holt and Callan, 2007); the greater the mean

PAP, the greater the supposed risk of RHF. Cattle with a mean PAP greater than 49 mmHg are considered to be at particularly high risk and should be moved to a lower elevation to avoid the onset of RHF. Since mean PAP is moderately heritable (h^2 of 0.34) (Shirley et al., 2008), it is reasonable to assume that we might be able to reduce the incidence of RHF among a calf crop by only breeding cattle with 'low' PAP measurements. To be accurate, PAP measures must be obtained at the altitude (or higher) at which the cattle are to be pastured.

PAP measurements performed at a lower elevation than the altitude at which the cattle are to inhabit provide little information: a low PAP measurement does not mean that it will also be low at a higher elevation; however, an individual with a high PAP measurement at low altitude should not be taken to higher altitude because it is already a high-risk candidate for RHF. PAP measurement has been largely successful at reducing the incidence of RHF among cattle located in the high country; however, because the technique requires special equipment and veterinary expertise, its application has been largely limited to the paternal line. It should also be noted that most PAP measures are collected from yearling bulls and replacement heifers. Therefore, additional research is needed to understand what these yearling measures infer to pre-weaning calves, and conversely, finishing steers.

Genetic research indicates mean PAP is a polygenic trait (Zeng et al., 2014). Recently, a variant of the gene encoding Hypoxia-Inducible Factor-2 (EPAS1) was discovered that predicts, in part, the tendency of beef cattle to develop elevated PAP when exposed to high altitude (Newman et al., 2015). This gene has been studied extensively in humans and appears to one of many important genes involved in pulmonary hypertension. Cumulatively, these reports suggest that genetic testing may provide solutions for improving cattle breeding practices and reducing the risk of pulmonary hypertension and right heart failure.

Respiratory issues

Unfortunately, the clinical signs of RHF are similar to those of respiratory disease (Glover and Newsom, 1915; Malherbe et al., 2012; Neary et al., 2013); consequently, many cases of RHF are likely misdiagnosed and mistreated. Further, calves with RHF may also have concurrent, or residual scarring from, respiratory disease (Neary et al., 2013). We have previously found that feedlot cattle treated for respiratory disease are 2 to 3 times more likely to develop RHF than cattle not treated for respiratory disease (Neary et al., 2015a). In an ongoing investigation into cattle mortality at one feedlot located at 3,000 ft. in the Texas Panhandle, we have identified that lesions of the pulmonary arteries and right ventricle are commonly associated with pneumonia. Furthermore, in many cases it appears that pneumonia was responsible for the development of RHF but it was RHF that was the cause of death. This raises many questions: Are necropsies commonly misdiagnosed as respiratory disease when in fact the animal died of RHF? Does pulmonary hypertension predispose cattle to respiratory disease, as well as RHF? Could pulmonary hypertension reduce the effectiveness of antimicrobials for treatment of respiratory disease?

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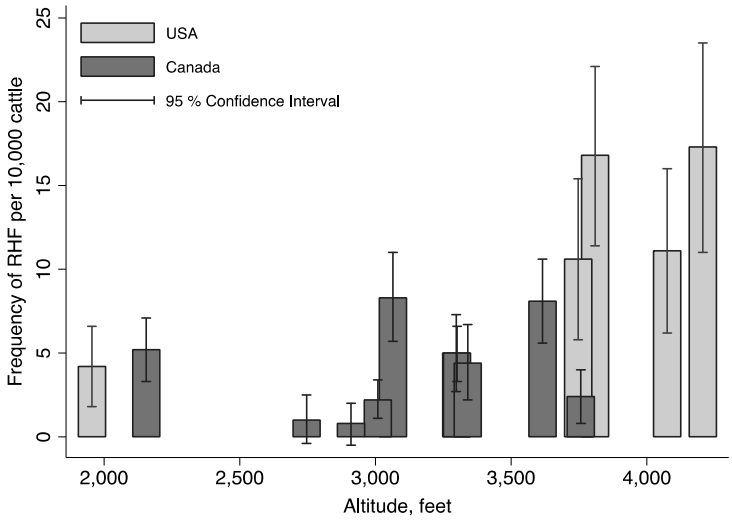

Figure 1. The risk of right-sided congestive heart failure (RHF) or brisket disease in Canadian and U.S. feedlots in 2012 according to feedlot altitude. The risk of RHF appears to be greater in feedlots located at higher altitudes.

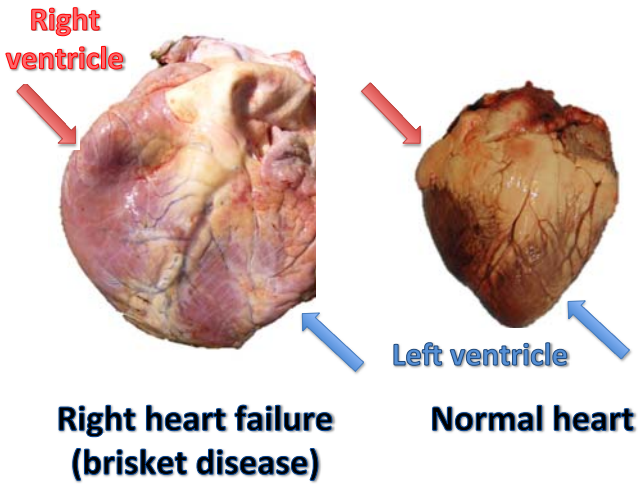

Figure 2. Narrowing of the pulmonary arteries in response to low levels of oxygen in the lung increases resistance to blood flow pumped through the lung by the right ventricle or chamber of the heart (top left arrows). The increased workload causes the muscular wall of the right ventricle to thicken in order to match the increased vascular resistance. Chronic pressure overload eventually causes the pumping capacity of the myocardium to decline, and the right ventricle to enlarge owing to incomplete filling and emptying during the cardiac cycle. Eventually, the heart can no longer function to pump blood through the pulmonary circulation – the valves begin to leak and contractions are further impaired as cardiac muscle cells die and are replaced with fibrotic lesions – leading to heart failure and death. The left ventricle (bottom right arrows) always forms the apex of the heart, the lowest part of the heart as it sits in the chest, and is closer to the diaphragm than the right ventricle.

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Fed Cattle Price Discovery and Risk Management

Ted Schroeder
Agricultural Economist
Center for Risk Management Education and Research
Beef Cattle Institute
Kansas State University
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Plains Nutrition Council
San Antonio, TX – April 14-15, 2016

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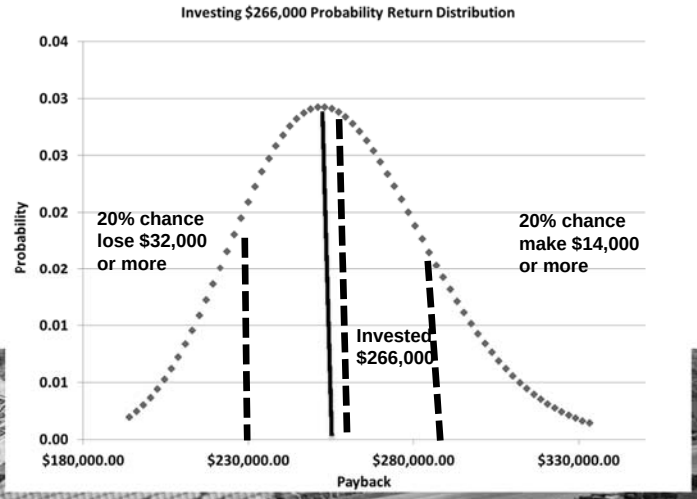
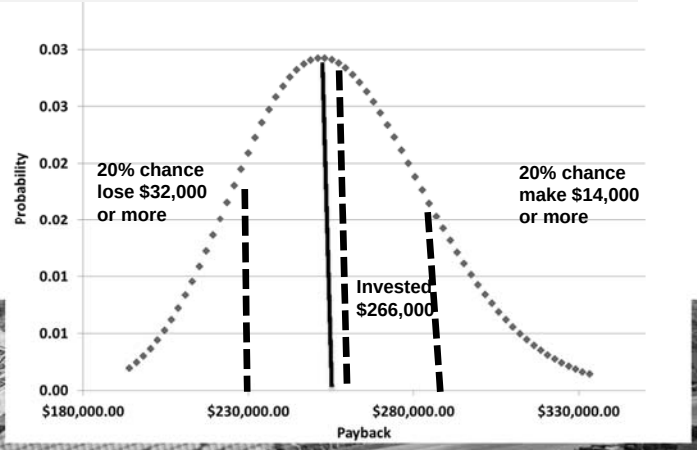
Lottery Proposition

Pay me $266,000 today
Distributional payback October 2016

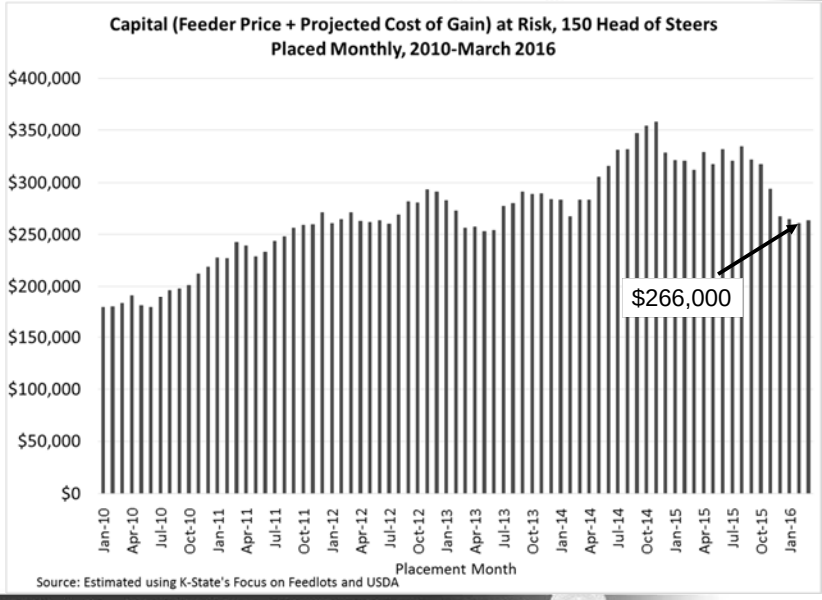


Lottery Proposition

Today's distribution for placing a pen of 150 yearling steers in feedlot



Cattle Feeding Capital At Risk



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Risk – Return Investment Tradeoff

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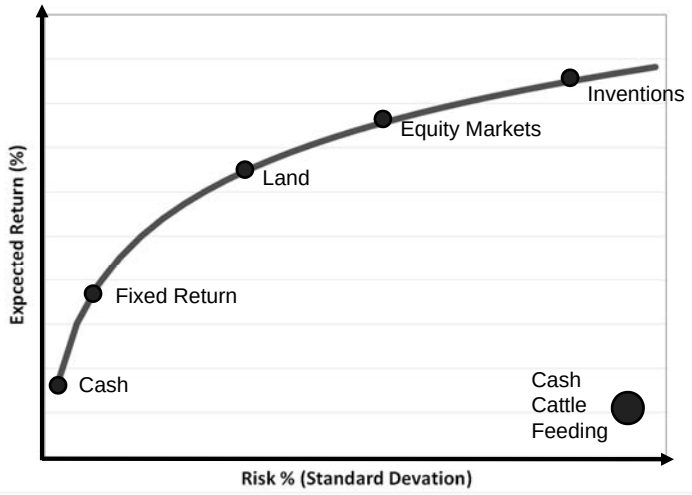
Risk – Return Investment Tradeoff



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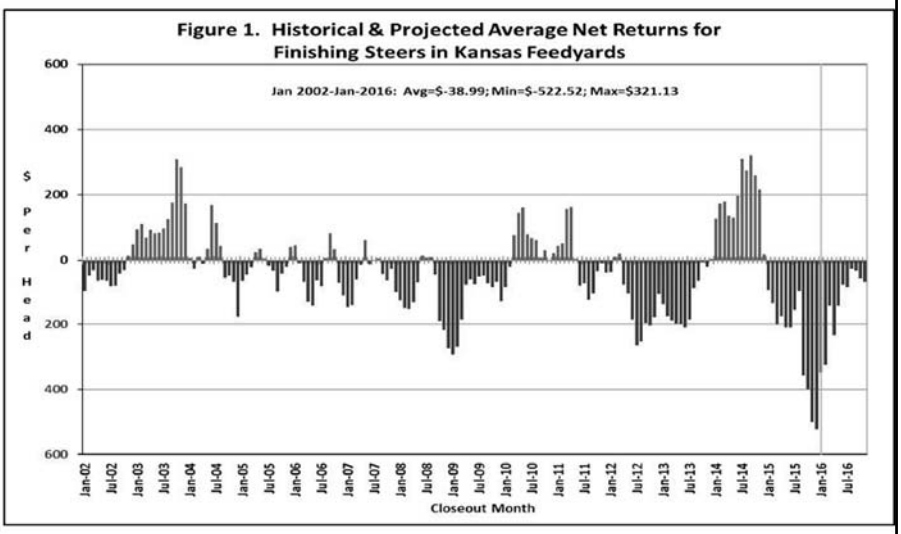
Cattle Feeding Risk



Source: G. Tonsor, K-State

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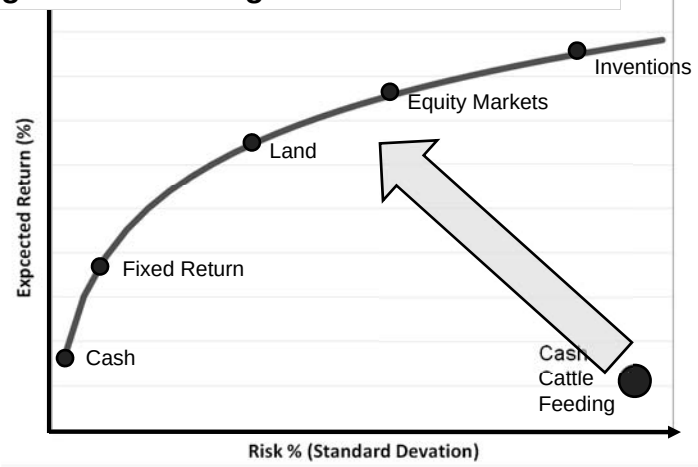
Risk – Return Investment Tradeoff

$10 Billion Question:
How to get cattle feeding closer to the frontier?



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Cattle Closer to Risk/Reward Frontier

Cattle Feeding Profitability

Total Revenue
- **Feeder Cost**
- Feed Cost
- Vet and processing
- Yardage
- Interest

= Net Return

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Cattle Closer to Risk/Reward Frontier

Starts with Feeder Cost – "Maintain optionality"
"you get what you pay for" but
"you own what you buy…."

- **National markets efficient**
- **Local markets inefficient**
- **Feeders are "storable"**

Medium and Large Frame Feeder Steer Auction Prices

Market		4-500#	5-600#	6-700#	7-800#	8-900#
Amarillo	03/18/16	$205.75	$190.37	$173.92	$158.49	$147.76
Billings	03/19/16	$227.20	$199.65	$181.34	$164.49	$153.72
Clovis	03/19/16	$237.03	$198.03	$175.76	$159.54	$148.71
Dodge City	03/18/16	$224.09	$202.33	$172.67	$166.22	$155.45
St Joe	03/18/16	$219.75	$210.98	$188.44	$173.11	$161.72

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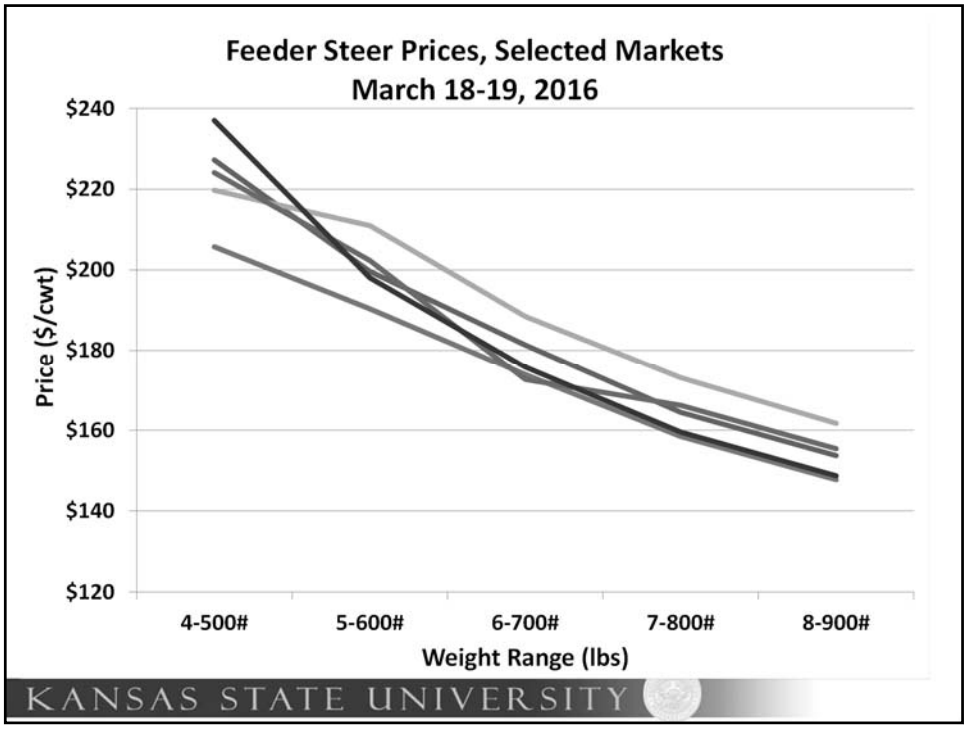
Feeder Steer Prices, Selected Markets
March 18-19, 2016
$240
$220
$200
$180
$160
$140
$120
Price ($/cwt)
4-500#
5-600#
6-700#
7-800#
8-900#
Weight Range (lbs)
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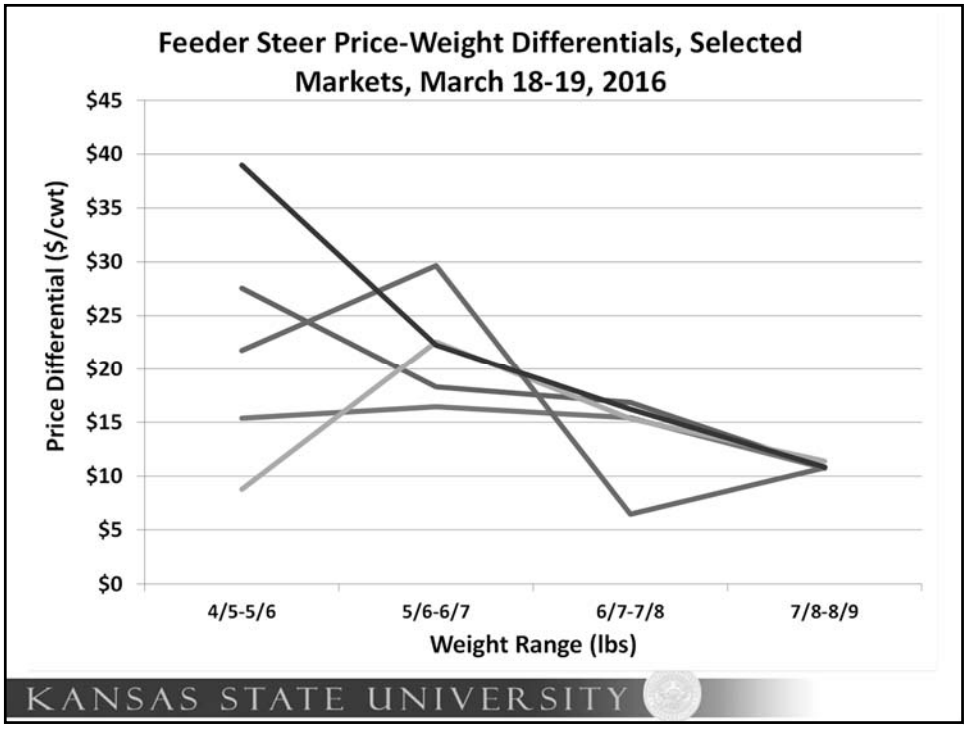
Feeder Steer Price-Weight Differentials, Selected
Markets, March 18-19, 2016
$45
$40
$35
$30
$25
$20
$15
$10
$5
$0
Price Differential ($/cwt)
4/5-5/6
5/6-6/7
6/7-7/8
7/8-8/9
Weight Range (lbs)
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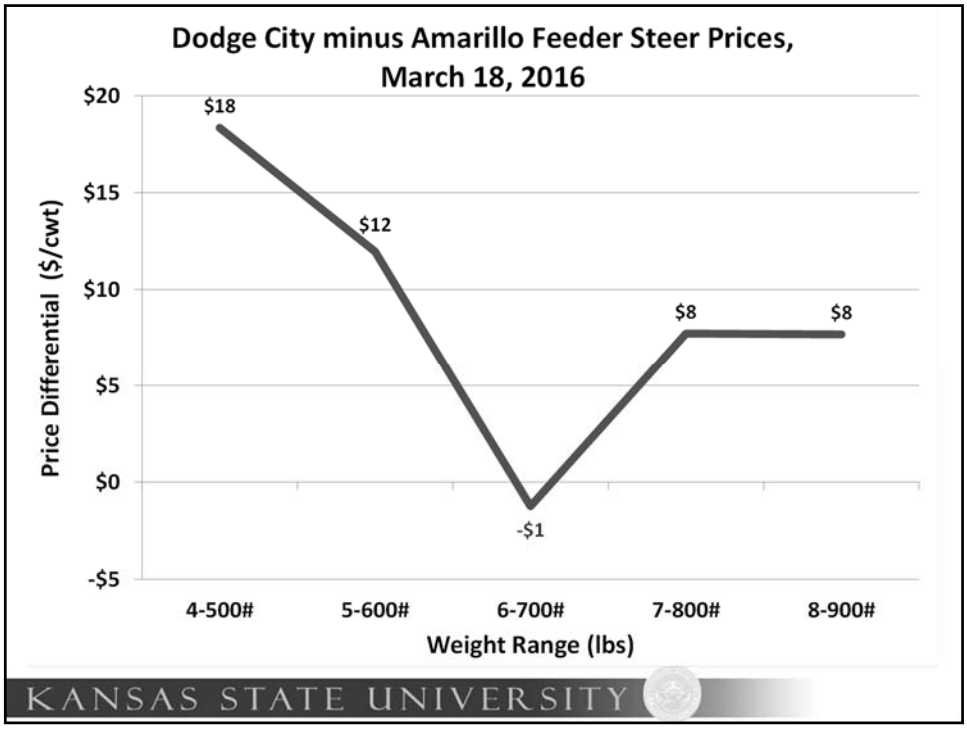

Cattle Closer to Risk/Reward Frontier

Cattle Feeding Profitability

Total Revenue
- **Feeder Cost**
- Feed Cost
- Vet and processing
- Yardage
- Interest

= Net Return

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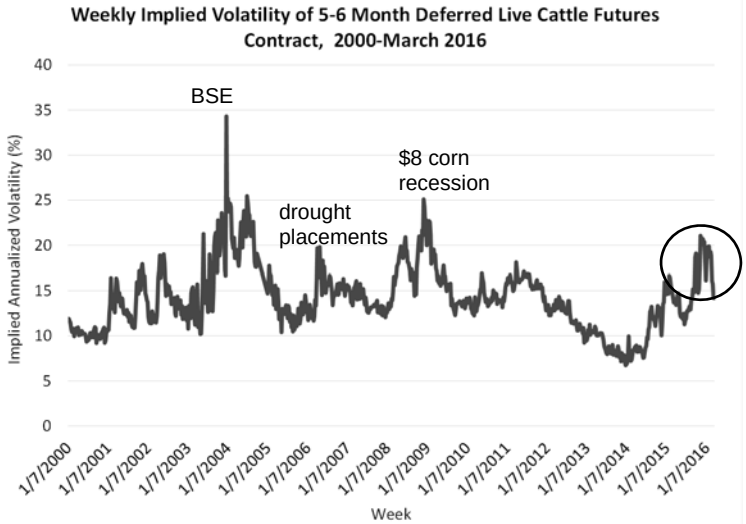
Cattle Closer to Risk/Reward Frontier

Fed Cattle Market



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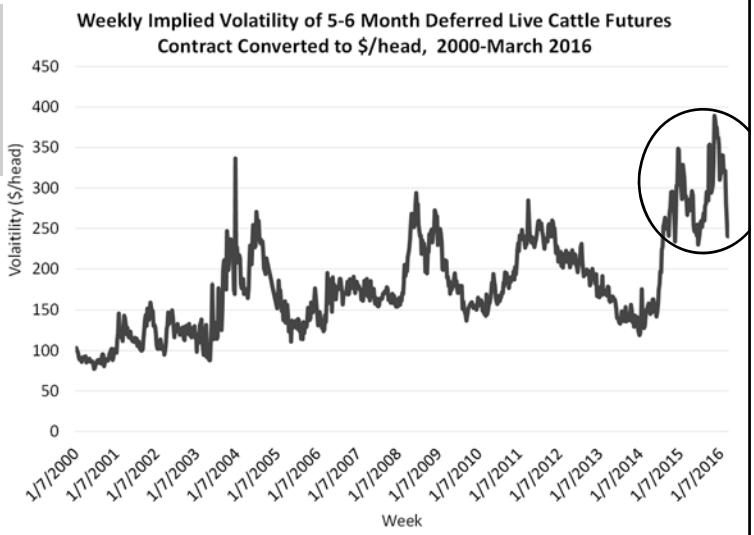
Cattle Closer to Risk/Reward Frontier

Fed Cattle Market

- High Risk
- Price protection essential



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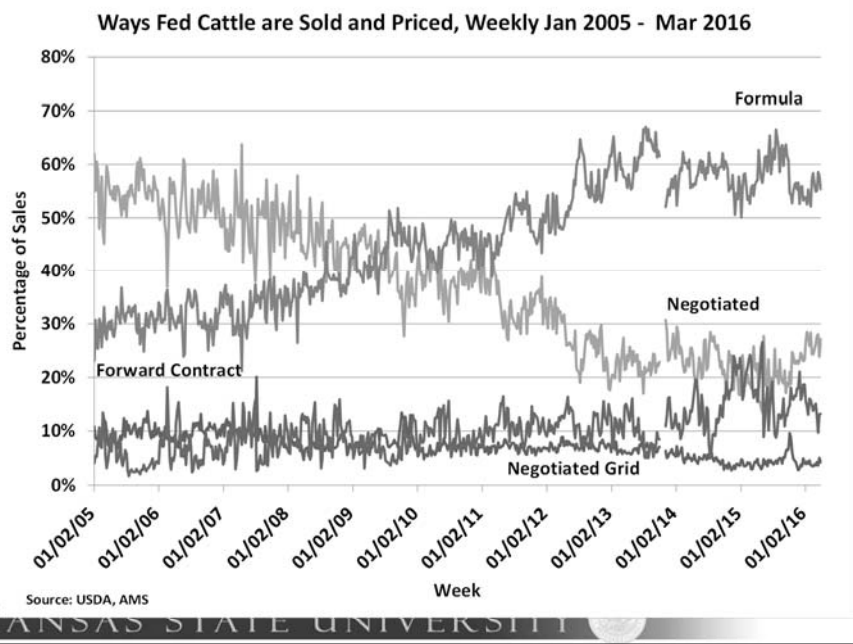
Fed Cattle Price Discovery



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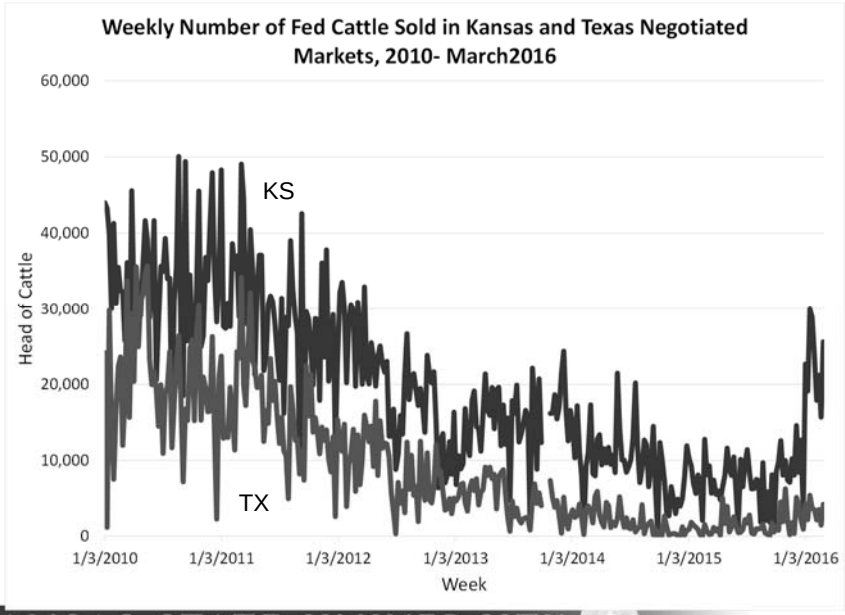
Fed Cattle Price Discovery



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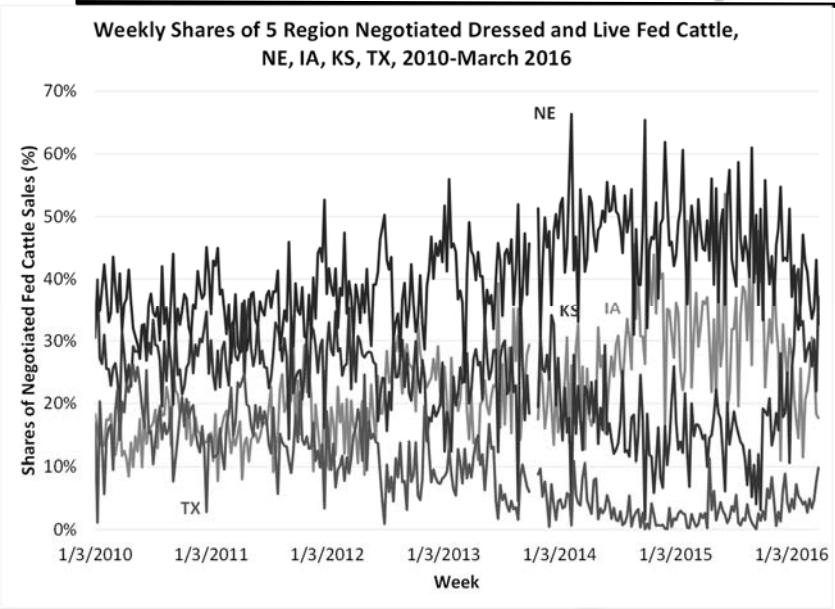
Fed Cattle Price Discovery



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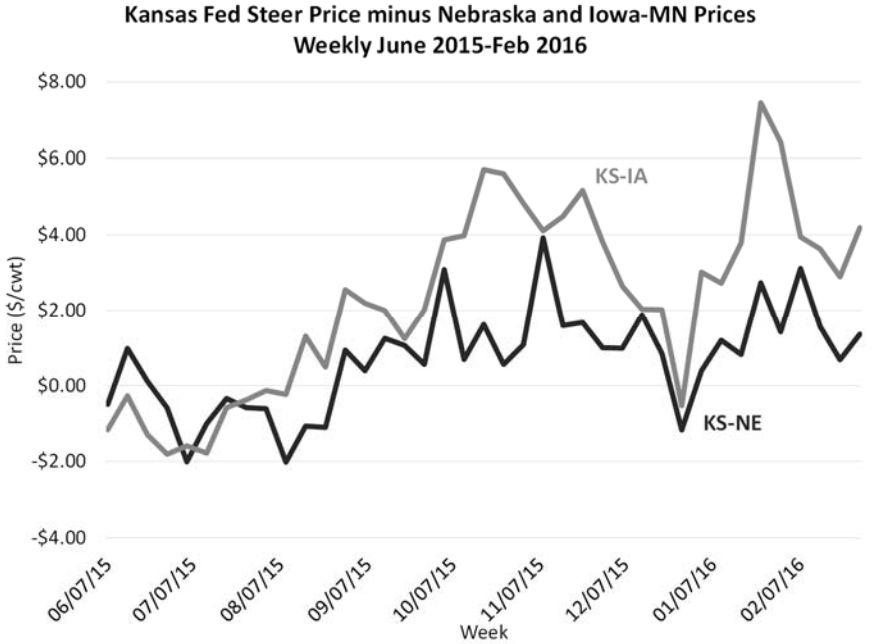

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Fed Cattle Price Discovery

One option electronic Auction for fed cattle

- **Platform efficiently bring together buyers/sellers**
- **Price discovery without direct trade negotiation costs**
- **Increase cash market liquidity?**

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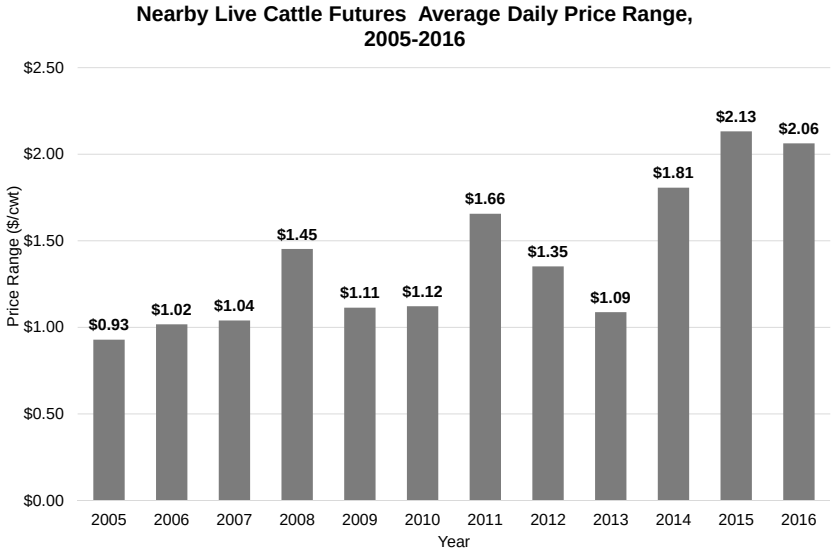

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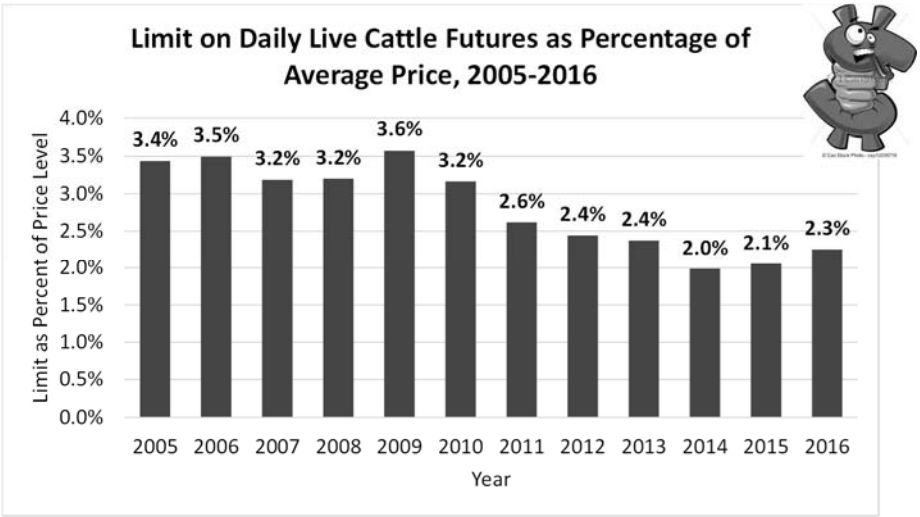

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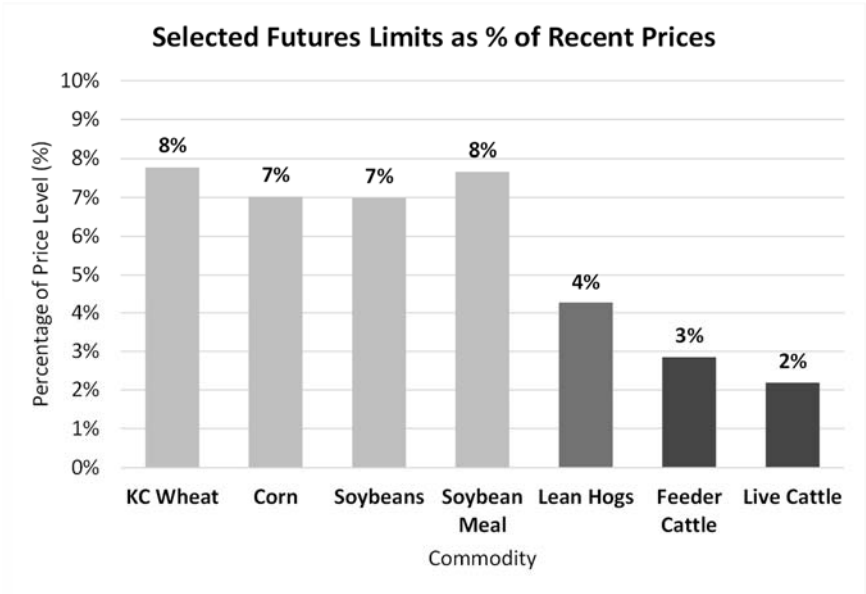

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Final Thoughts

1. Large capital at risk feeding cattle
2. Cattle Feeding market risk historically very high
3. Returns low and risky
4. Risk Management Starts before calves bought/placed
5. Risk management in fed cattle essential for survival
6. Price discovery has become important dimension of risk

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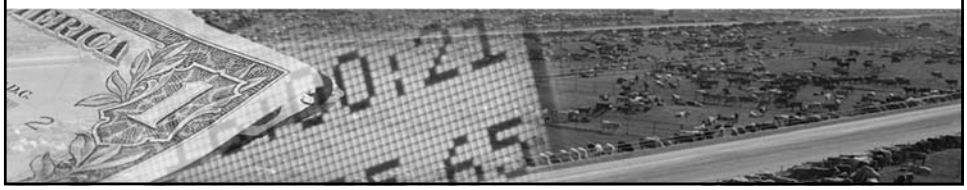

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Graduate Student Poster Presentations

Feasibility of alternative feeding methods in limit-fed cow-calf systems *J. R. Baber, J. E. Sawyer, D. P. Anderson, J. W. Richardson, L. A. Trubenbach, and T. A. Wickersham, Texas A&M Univ., College Station*

Drought and land values challenge the economic sustainability of cow-calf production. Creating an intensified cow-calf system allows producers to depend less on forage production. However, delivery of limit-fed, total mixed rations brings greater fixed costs and creates logistical challenges, preventing smaller producers from capturing benefits associated with intensified systems. Objectives of this study included quantifying differences in cow performance and net returns with alternative feeding methods in cow-calf systems. Ninety-five mid- to late-gestation cows (1108 ± 332 lb) were used in a 112-d trial. Cows were stratified by weight, BCS, age, and days of gestation and were randomly assigned to one of 12 pens in a randomized complete block design. Treatments were limit-fed total mixed ration (TMR), forage and concentrate portions of the limit-fed TMR separated and fed 12 h apart (SEP), and *ad libitum* Bermudagrass hay (HAY). Limit-fed treatments were fed a diet of wheat straw (35%), cracked corn (29%), dried distiller's grains (27%), and premix (9%) formulated to contain 0.71 Mcal NE_m/lb and fed to deliver 80% of NRC predicted NE_m requirements. Body weight, BCS, and back fat measures were collected every 28 d. To evaluate the net returns of alternative feeding systems, a stochastic simulation model was developed using a 200 cow operation. Stochastic variables in the model included weaning weights, prices of weaned steers and heifers, and feed ingredient prices. To estimate ingredient and cattle prices, multivariate empirical distributions were used, which incorporates historical variability and correlations in stochastic forecasted prices. A budget for each system was developed to incorporate stochastic variables in the model. Cow performance was not significantly impacted with no differences in final BW (1143 lb; $P = 0.72$) or final BCS (5.6; $P = 0.67$). Treatment tended to affect final RE ($P = 0.06$); TMR (137.1 Mcal) and SEP (98.9 Mcal) had RE greater than 0 ($P \leq 0.04$), but RE for HAY (-14.6 Mcal) did not differ from 0 ($P \geq 0.72$). Net returns for limit-fed systems (TMR, $130.66 per cow; SEP, $160.73 per cow) were greater than the HAY ($72.41 per cow). Reduced feed costs in limit-fed systems ($168.90 per cow) offset increased fixed costs ($225.65 and $208.65 per cow, TMR and SEP, respectively) associated with limit-fed systems compared to HAY ($260.67 and $205.85 per cow, feed and fixed costs, respectively). There is greater probability of net returns being negative for HAY (35%) than TMR (22%) or SEP (19%). Additionally, more coefficient variation, or risk, is associated with HAY ($271.50 per cow). Limit-feeding of TMR or separate delivery of forage and concentrate rations sustained cow performance compared to *ad libitum* hay consumption. Economic analysis suggests limit-feeding cattle is preferred to hay feeding, and that separate delivery of forage and concentrate would be most profitable and least risky.

Chromium propionate supplementation alters feedlot performance and GLUT4 activity in feedlot steers *J.O. Baggerman[1], Z.K. Smith[1], A.J. Thompson[1], J.K. Kim[1], W. Rounds[2], and B.J. Johnson[1], [1]Texas Tech Univ., Lubbock, [2]Kemin Industries, Des Moines, IA*

The objective was to evaluate the effects of increasing concentrations of chromium propionate (CrP) on feedlot performance, blood parameters, carcass characteristics, and skeletal muscle changes over time in feedlot steers. Crossbred steers (n = 32) were blocked by BW, assigned to one of 16 pens, and each pen was randomly assigned to one of four treatments: control, 150 ppb supplemental CrP (KemTRACE® Chromium 0.04%, Kemin Industries, Des Moines, IA), 300

ppb supplemental CrP, and 450 ppb supplemental CrP. Steers were fed 1X daily *ad libitum* a steam-flaked corn based diet, and the treatment was topdressed at the time of feeding. Body weights, blood samples, and skeletal muscle biopsies were collected before time of feeding on d 0, 28, 56, 91, 119, and 147. Blood sera were harvested for analysis of glucose, insulin, serum urea nitrogen (SUN), and NEFA concentrations. Skeletal muscle biopsy samples were used for immunohistochemical analysis. Starting on d 56 through the end of the trial, cattle fed the 450 ppb treatment were the heaviest ($P < 0.05$). A linear effect ($P < 0.05$) of treatment on BW and ADG was observed starting on d 56 until the end of the trial. For HCW, there was also a linear effect of treatment with the greatest HCW in the cattle fed the 450 ppb treatment ($P < 0.05$). There was no effect of treatment on any blood parameter measured ($P > 0.05$). For skeletal muscle fiber cross-sectional area, there was a treatment by day interaction ($P < 0.05$) with the greatest increase in the 450 ppb treatment group. A treatment by day interaction was also observed for fiber type distribution ($P < 0.05$). Density of total GLUT4 decreased over time for all treatments ($P < 0.05$) with the treatments receiving CrP having less of a decrease than the control group ($P < 0.05$). Internalization of GLUT4 was increased in the 300 ppb and 450 ppb treatments ($P < 0.05$). For total nuclei density and myonuclei density, there were treatment by day interactions ($P < 0.05$), where the 450 ppb treatment exhibited a greater density of total nuclei and myonuclei on d 147. These results indicated supplementation of 450 ppb CrP increases HCW, possibly due to changes in GLUT4 activity in skeletal muscle.

Predicting feedlot growth performance over the feeding period utilizing steer age and BW

C. J. Bittner, A. W. Watson, J. C. MacDonald, and G. E. Erickson Univ. of Nebraska-Lincoln*

A pooled-analysis of University of Nebraska-Lincoln feedlot pens examined the effects of steer age and BW on feedlot growth performance in studies conducted from 2002-2015. For data analysis, pens were divided into 3 subclasses based on steer age (calf-fed, short yearling, or long yearling) when they started the finishing diet. Calf-feds were defined as starting the finishing diet in the fall, usually November, and then finished the following spring, typically May. Short yearlings grazed corn residue from November to April, and then started on the finishing diet in May and were harvested in September. Long yearlings grazed corn residue from November to April, pasture from May to September, and then started on the finishing diet in October and were usually harvested in January. Furthermore, within each steer age class, pen means were grouped based upon initial BW (500 to 1200 lb., in 100 lb. increments) when starting the finishing diet. There were 1,002 pens of calf-feds, 1,114 pens of short yearlings, and 435 pens of long yearlings. As initial weight group increased, DMI (averaged over the entire feeding period) increased quadratically ($P < 0.01$) in calf-fed steers and averaged 22.7 lb/d over the entire feeding period. However, in short yearlings, DMI increased linearly ($P < 0.01$) as initial weight group increased, with DMI averaging 25.7 lb/d. Likewise, DMI increased linearly ($P < 0.01$) as initial weight group increased for long yearlings and averaged 26.7 lb/d. For all age groups and initial weight class of steers, calculating DMI as a percent of current BW was relatively constant over the entire feeding period with a range of 2.2 to 2.6%. Intake as percent of current BW was greatest early in the finishing period and decreased as days on feed increased. A quadratic increase ($P = 0.02$) in ADG was observed in calf-feds as initial weight group increased. No differences ($P > 0.21$) in ADG were observed for short yearlings and long yearlings. Feed efficiency decreased linearly ($P < 0.01$) as initial weight group increased for all age groups of steers (calf-fed, short yearling, and long yearling). As expected, feed efficiency was numerically greatest in calf-fed (0.170) steers, whereas short yearling (0.151) and long yearlings (0.149) were

similar. In conclusion, evaluating intake as a percent of current BW reduces variation due to steer age and BW; however, as days on feed increases, intake as a percent of BW decreases. Predicting intake and growth performance over the entire feeding period is dependent upon steer age and initial weight when starting the finishing diet.

Influence of feed efficiency on meat tenderness attributes of beef steers: implications for the selection of improved feed efficiency *C.P. Blank, J.R. Russell, S.M. Lonergan, S.L. Hansen, Iowa State Univ., Ames*

Inefficiencies in the production of beef compared to other protein sources has brought feed efficiency (FE) to the forefront of the industry as a priority for the sustainability of beef production. However, previous work has indicated that highly efficient cattle have greater calpastatin activity. The proteolytic calpain system regulates the rate of protein turnover in which the calcium-dependent calpains degrade proteins. However, calpastatin inhibits calpain thus reducing the rate of protein turnover, potentially producing a less tender product. Consumer evaluation of beef has indicated that tenderness is the number one indicator of quality. Therefore, the objective of this study was to assess the effects of beef cattle FE on meat tenderness. Crossbred steers grown at the University of Missouri (76 d) on a whole-shell corn (Corn, $n = 89$) or roughage-based diet (Rough, $n = 90$), were phenotypically classified for FE based on residual feed intake (RFI) calculations with an average BW of 422 ± 31 kg. Within each growing phase (GP) diet, the 12 greatest (HFE; average RFI -3.33 ± .77, SD) and 12 least (LFE; average RFI 2.90 ± .94) efficient steers (48 steers total) were selected for further analysis. Steers were shipped to Iowa State University (ISU) and within each GP diet and FE classification steers were equally assigned to GrowSafe equipped pens and transitioned to corn (Corn) or byproduct-based diet (Byp) for an 87 d finishing phase (FP). Optaflexx (200mg/d) was fed for 28-d prior to harvest. Rib sections were collected from the 48 steers, and samples were immediately analyzed for calpastatin activity or frozen for mu-calpain and troponin-T protein analysis. Another steak was aged under retail conditions for 14-days prior to analysis of troponin-T and Warner Bratzler shear force (WBSF; d14). Data were analyzed using PROC MIXED of SAS with the fixed effects of MU diet (rough and corn), ISU diet (byproduct and corn), FE classification (highly and lowly efficient), and the interactions; significance was determined at $P \leq 0.05$. No 3-way or 2-way interactions ($P \geq 0.19$) were observed for any data, therefore main effects are presented ($n = 24$ per treatment). Day 2 calpastatin activity tended ($P = 0.10$) to be greater in HFE steers than LFE steers, but was not affected by GP or FP diets ($P \geq 0.19$). However, there were no differences noted in d2 mu-calpain autolysis ($P \geq 0.15$) or d2 troponin-t degradation ($P \geq 0.12$) due to GP diet, FP diet, or FE classification. Increased degradation of relative troponin-T indicates greater protein degradation and d14 troponin-T was greater in Corn vs. Byp finished steers ($P = 0.005$). Interestingly, roughage grown steers had greater d14 WBSF than steers grown on corn ($P = 0.05$), suggesting consumers may find steaks from cattle grown on roughage-based diets less tender. These data suggest that selection for FE does not pose an immediate threat to beef tenderness as cattle that were phenotypically extreme for feed efficiency during the GP in this study expressed minimal differences in tenderness attributes. However, growing cattle on roughage-based diets or finishing on a fibrous by-product diet negatively affected markers of beef tenderness. Diet type and FE classification may independently affect meat tenderness; however, more work is needed with greater numbers of cattle to better understand the impact of FE phenotype or diet type on beef tenderness.

Effect of winter distillers grains supplementation level on spayed heifer performance in a long yearling system *R. G. Bondurant, B. L. Nuttelman, J. C. MacDonald, and T. J. Klopfenstein; Department of Animal Sciences, Univ. of Nebraska-Lincoln*

A two-yr study was conducted utilizing 220 spayed heifers (BW=515; SD=51 lb) each yr to determine the optimal level of modified distillers grains plus solubles (MDGS) supplementation during winter grazing. The 2 yr of data were analyzed separately due to a yr x trt interaction for summer and feedlot gains ($P \leq 0.03$). Treatments included the supplementation of MDGS at 3, 5, and 7 lb heifer daily during the winter corn residue grazing phase. Upon completion of winter corn residue grazing, heifers grazed smooth bromegrass followed by native range. Heifers were then finished on a common ration. An economic analysis was completed using 5 yr average of corn $/bu, feeder heifer, live fed heifer, and carcass base prices. For MDGS, a value of 85% corn price (DM basis) was assumed while winter residue rent was assumed $0.35/d and summer pasture rent $0.90/d. For both yr, ending BW and ADG for the winter phase increased linearly ($P < 0.01$), and summer phase ADG decreased linearly ($P < 0.01$) as winter supplementation level increased. For yr 1, ending BW for summer was not different ($P = 0.36$) however, yr 2 summer ending BW increased linearly ($P < 0.01$) from 914 to 954 lb as winter supplement increased. For yr 1, there were no differences ($P \geq 0.30$) in finishing performance and total system ADG (average of winter, summer, and finishing) was not different ($P = 0.91$) among treatments. In yr 2, final BW linearly increased ($P = 0.04$) from 1302 to 1357 lb due to winter MDGS supplementation. For both yr, ADG and G:F were not different ($P \geq 0.25$) during the fall finishing phase. Year 2 total system ADG linearly increased ($P = 0.02$) from 1.83 to 1.96 lb/d as MDGS supplementation increased during the previous winter. There were no differences in carcass characteristics ($P \geq 0.27$) for yr 1. However, in yr 2 HCW increased linearly ($P = 0.04$) from 819 to 855 lb as winter supplementation increased. Similar with yr 1, there was no difference in LM area ($P = 0.23$) or marbling score ($P = 0.28$). Contrary to yr 1, there was a linear increase ($P = 0.04$) in 12th rib back fat thickness and consequently a tendency for linear increase in calculated yield grade ($P = 0.10$) as heifers were supplemented with increasing levels of MDGS in the winter phase. For both yr winter supplementation and total winter costs linearly increased ($P < 0.01$). For yr 1 total feedlot costs were not different while yr 2 tended ($P = 0.09$) to increase from $462.31 to $473.96 when supplementing 3 or 5 lb/d winter MDGS and decreased to $463.58 when supplemented 7 lb/d winter MDGS. Total system costs linearly increased ($P \leq 0.03$) as winter supplementation increased from 3 to 7 lb/d for both yr. Year 1 live and carcass based revenue were not different ($P \geq 0.69$) while in yr 2, live and carcass based revenue linearly increased ($P = 0.04$) as winter supplementation increased from 3 to 7 lb/d. Live and carcass based profit/heifer linearly decreased ($P \leq 0.02$) for yr 1 while neither were different for yr 2 ($P \geq 0.43$) as winter supplementation increased from 3 to 7 lb/d. Level of winter supplementation had no effect on finishing ADG or G:F when backgrounded on summer grass without supplement prior to feedlot arrival. Supplementing heifers at 7 lb/d MDGS during winter corn residue grazing has the potential to increase finished weight and profit/heifer.

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The effect of feeding a yeast supplement or finely ground fiber during the summer on body temperature, performance, and blood metabolites of finishing steers *B. M. Boyd[1], T. L. Mader[2], C. Bittner[1], F. H. Hilscher[1], G. Wijffels[3], J B. Gaughan[4], M. Sullivan[4], J. Cawdell-Smith[4], and G. E. Erickson[1],[1] Univ. of Nebraska-Lincoln,[2] Mader Consulting, Gretna, NE,[3] CSIRO,Queensland, Australia, [4] Univ. of Queensland, Australia*
Crossbred beef steers (n=96) were utilized in a study conducted at the University of Nebraska-Lincoln Agricultural Research and Development Center research feedlot near Mead, NE to determine the effect of feeding Agrimos (Lallemand Animal Nutrition; Montreal, Canada) and 1.0-in ground wheat straw to finishing steers during the summer on body temperature and panting score in addition to performance, carcass characteristics and blood metabolites. Three treatments with four replications per treatment were set up in a completely randomized design. Treatments consisted of a basal control diet (CON); consisting of 68.5% corn, 20% modified distillers grains plus solubles, 7.5% sorghum silage, and 4% supplement, the inclusion of Agrimos (MOS; 30g/steer daily), and 1.0-in ground wheat straw replacing 5% corn (WHT). Cattle were stratified by initial BW between pens and pen was assigned randomly to treatment. Rumen boluses to collect body temperature were inserted on d 21 of the trial after cattle were adapted to finishing diets. Blood was collected in July and August (7 collection weeks) of the trial via jugular venous puncture. There were no differences ($P > 0.19$) observed for final BW, ADG, and DMI among treatments. Additionally, no difference ($P > 0.24$) was observed for carcass-adjusted final BW or ADG. Feed efficiency was decreased ($P < 0.02$) on both a live- and carcass-adjusted basis for cattle fed WHT when compared to CON and MOS. Hot carcass weight, dressing %, LM area, and marbling score were not different ($P > 0.36$) among treatments. Cattle fed the CON had greater 12th rib fat depth and USDA yield grade ($P < 0.02$) than cattle fed WHT and MOS. Both average and maximum body temperatures were greater ($P < 0.01$) for cattle fed MOS than for cattle fed CON or WHT. There was no difference ($P = 0.18$) for area under the curve body temperature between treatments. Panting scores were least ($P < 0.01$) for cattle fed the WHT when compared to CON and MOS. Time and treatment interactions ($P < 0.05$) were observed for bilirubin, blood urea nitrogen, calcium, chloride, carbon dioxide, creatinine, potassium, lactate dehydrogenase, phosphorus, total protein, triglyceride, uric acid, red blood cell count, hemoglobin, and hematocrit levels. No effect on animal performance was realized from the addition of Agrimos to the diet; however, body temperature was increased slightly. Adding 5% finely ground wheat straw decreased F:G and reduced panting score but did not affect body temperature.

Evaluation of the relative contribution of protein in distillers grains in finishing diets on performance and carcass characterstics *Z. E. Carlson, G. E. Erickson, J. C. MacDonald, and M. K. Luebbe, Univ. of Nebraska-Lincoln*
The ethanol industry has adopted technologies to improve ethanol production potentially increasing the protein content of distillers grains. Crossbred yearling steers (n = 324; initial BW = 641 lb; SD = 53) were utilized in a randomized block design to determine the relative contributions of excess rumen undegradable protein on the energy value of wet distillers grains plus solubles (WDGS). Pen was the experimental unit and initial BW block (n = 2) was treated as a fixed effect. There were a total of six dietary treatments (6 replications). Protein in WDGS was simulated using corn gluten meal (CGM; 8.75 and 17.5% inclusion; DM basis) to provide similar rumen undegradable protein as 20 and 40% WDGS (DM basis), respectively. Linear and

quadratic effects of WDGS inclusion and protein (CGM) concentration were evaluated. Pre-planned pairwise comparisons were used to determine effects of solubles inclusion to 17.5% CGM diet and feeding value of protein from WDGS. A linear decrease ($P < 0.01$) in DMI was observed as WDGS inclusion increased from 0% in the control (22.6 lb) to 40% (21.4 lb); G:F increased linearly ($P < 0.01$) as WDGS increased from 0% (0.161) to 40% (0.176). A quadratic increase ($P = 0.04$) in ADG was observed as CGM increased from 0% (3.63 lb) to 17.5% (3.81 lb). A linear increase ($P < 0.01$) in G:F was observed as CGM (protein) increased from 0% (0.161) to 17.5% (0.169). Addition of 10% solubles (DM basis) to the 17.5% CGM diet decreased ($P = 0.04$) ADG. Isolating the protein portion of 20% WDGS by feeding 8.75% CGM decreased ($P < 0.01$) G:F compared to 20% WDGS. Similarly, protein from 40% WDGS replaced by 17.5% CGM increased ($P < 0.01$) DMI and decreased ($P < 0.01$) G:F compared to 40% WDGS. A quadratic response ($P = 0.04$) in HCW was observed as CGM increased from 0% (833 lb) to 17.5% (855 lb). The inclusion of solubles decreased ($P = 0.04$) HCW when added to 17.5% CGM. Using the calculated G:F of 0.161 for the control, the calculated feeding values relative to corn were: 134%, 125%, 110%, 129%, and 121% for, 20% WDGS, 40% WDGS, 8.75% CGM, 17.5% CGM, and 17.5% CGM with 10% solubles, respectively. Dietary net energy for maintenance and gain were calculated from animal performance. As WDGS inclusion increased from 0 to 40%, dietary net energy increased ($P < 0.01$) linearly. Similarly, as protein concentration increased from 0 to 17.5% so did dietary net energy ($P < 0.01$). For both 20PRO and 40PRO dietary net energy was lower ($P < 0.01$) than their respective WDGS diet. There were no dietary net energy differences between 40PRO and 40PRO-SOL. Excess rumen undegradable protein from distillers grains used as an energy source accounts for the majority of the energy value response observed when feeding WDGS.

Effect of dietary energy intake on nutrient utilization, performance, and maintenance requirements in late gestation cows and their calves *N. M. Early, J. E. Sawyer, L. A. Trubenbach, C. J. Boardman, J. R. Baber, N. L. Bell, T. A. Wickersham, Texas A&M Univ., College Station*

Sustainability of the U.S. cow-calf sector is vulnerable to drought and elevated land prices. Limit-feeding high-concentrate diets to cows in confinement may mitigate risks associated with unreliable forage availability and reduce capitalization requirements while increasing efficiency of nutrient utilization. This strategy was investigated using 60 multiparous, late-gestation beef cows (462 kg initial BW). Cows were blocked by BW and individually fed one of four treatments (70, 85, 100, and 115% of NRC-predicted maintenance energy) in Calan gates for an average of 71 d prior to calving. Diets consisted of 2.00 kg of wheat straw (2.5% CP; 79% NDF) and one of four levels of a mixture of corn (45%), distillers' grain (42%) and premix (13%) fed at 2.89, 3.67, 4.46, and 5.28 kg/d to correspond with the 70, 85, 100, and 115% treatments. Following calving, pairs were managed as a group on pasture. Digestion was determined using ADIA as an internal marker. Cows were weighed on days 0, 22, 52, at parturition, at 60, 90, 120 and 160 days postpartum, and at weaning (d 270). Cow body energy was estimated pre-partum on days 0 and 52 of the limit-feeding period using back fat values measured between the 12th and 13th rib via ultrasonography. Digestible energy intake increased linearly (5.92, 6.78, 7.77 and 8.86 Mcal/d for 70, 85, 100, and 115%; $P < 0.01$) per design; ME intake responded similarly (4.85, 5.56, 6.37 and 7.26 Mcal/d). No effects ($P > 0.05$) for diet digestion were observed; DM digestion averaged 62%. Retained energy during the limit-feeding period (d 0 to 52) increased linearly ($P < 0.01$) from 46.6 Mcal for 70% to 50.7, 106.3, and 123.8 Mcal for 85, 100, and

115%. Body weight gain increased linearly over the same time period ($P < 0.01$) from 0.7 kg for 70% to 3.6, 17.7, and 24.2 kg for 85, 100, and 115%. Calf birth weight increased linearly ($P = 0.01$) from 32.5 kg for 70% to 35.5, 35.2, and 36.8 kg for 85, 100, and 115%. Brix (%) values for colostrum at parturition and 24 h postpartum did not differ ($P > 0.05$) as a result of dietary treatment. Immunoglobulin G levels in calf serum collected at birth, 24 h and 7 d did not differ ($P > 0.05$) and averaged 0, 4,749, and 4,464 mg/dL, respectively. Cow body weights remained greater (linear, $P < 0.05$) in cows fed increasing levels of energy at days 60 and 90 postpartum; however, treatments no longer differed ($P > 0.05$) at 120 or 160 days postpartum or at weaning their calves (d 270). Level of energy intake during gestation did not result in significant differences ($P > 0.05$) in calf weights at 60, 90, 120 or 160 days postpartum or at weaning (averaged 206 kg). Cow 30 and 60 d conception rates were 82% and 98%, respectively. Production goals of the cow-calf sector were successfully met by limit-feeding late-gestation beef cows at intake levels at least 70% of NRC-predicted energy requirements for maintenance.

Effect of dry-rolled corn supplementation on gas emissions, performance, and energetic losses of steers grazing wheat pasture *P. J. Ebert[1], J. S. Jennings[2], C. L. Brauer[2], A. L. Shreck[3], N. A. Cole[3], and E. A. Bailey[1], [1]West Texas A&M University, Canyon, [2]Texas A&M AgriLife Research, Amarillo, [3] USDA-Agricultural Research Service, Bushland, TX*
Research on cattle grazing wheat pasture, a principal grazing resource for growing cattle in the High Plains, are lacking in terms of gas emissions and energy losses. Thirteen Angus-cross steers (initial BW = 436 $\pm$ 24 kg) were used in a crossover design to evaluate the effects of corn supplementation on gas emissions, performance, and energetic losses of steers grazing wheat pasture. Steers were allowed *ad libitum* access to wheat pasture (1.2 steers/ha), and were individually supplemented one of two treatments daily for two 30 d periods. Treatments included either 0.2 kg of pelleted wheat middlings (CON), or a dry-rolled corn supplement fed at 0.5% of BW plus 0.2 kg of pelleted wheat middlings (SUPP). After the initial 30 d period, treatments were alternated and steers were supplemented an additional 30 d. Fecal output was determined with titanium dioxide as an external marker. Titanium dioxide was dosed at 15g/d for 14 d before collection period and 6 d during collection period. In vitro analysis of wheat forage was determined to estimate DM digestibility of the wheat forage for each 30 d period. Forage intake was calculated using the determined fecal output and forage digestibility. Ruminal CH_4 and CO_2 fluxes were measured using a GreenFeed (C-Lock Inc., Rapid City, SD) system. Urine energy loss was estimated to be 1.4% of GE intake. Oxygen production was estimated from CO_2 production, assuming a respiratory quotient of 1.05. Forage intake as a percent of BW did not differ ($P = 0.15$) between CON (3.22%) and SUPP (3.61%). Average daily gain for CON and the SUPP averaged 1.4 kg and 1.3 kg, respectively, and was not influenced ($P = 0.54$) by supplementation. There were no differences ($P \geq 0.63$) among treatments for OM digestibility (CON: 84.9%; SUPP: 84.6%) and NDF digestibility (CON: 82.5%; SUPP: 83.1%). Carbon dioxide excreted (CON: 9.8 kg/d; SUPP: 10.5 kg/d) tended to be less ($P = 0.08$) for CON. No differences ($P = 0.43$) were observed in CH_4 emissions among CON and the SUPP supplement (334 and 351 g CH_4/d, respectively). Corn supplementation decreased ($P = 0.02$) CH_4 g/kg of DMI by 20.5%. Methane as percent of GE intake was decreased ($P = 0.02$) by 21.6% when steers consumed the SUPP compared to CON. Also, heat production as a percent of GE intake was decreased ($P = 0.03$) when steers consumed the SUPP. Under the conditions of this experiment, cereal grain supplementation reduced CH_4 emissions.

Effects of roughage inclusion and particle size on performance and rumination behavior of finishing beef steers *W.W. Gentry[1], C.P. Weiss[1], C.M. Meredith[1], C.L. Brauer[1], F.T. McCollum[1], N.A. Cole[2], and J.S. Jennings[1], [1]Texas A & M AgriLife Research and Extension Center, Amarillo, [2]USDA ARS Conservation and Production Research Laboratory, Bushland, TX*
This experiment was conducted to determine the effects of feeding 5 or 10% corn stalks at various grind sizes with 30 or 25% wet corn gluten feed (WCGF), respectively, on rumination behavior, animal performance, and carcass characteristics of finishing beef steers. Fifty-one crossbred beef steers (BW = 881 ± 8 lbs), outfitted with rumination monitoring collars, were used in a randomized complete block design. Corn stalks were either passed through a commercial tub grinder once (large grind; LG) or twice (short grind; SG). Steam-flaked corn-based treatment diets included: 10% SG with 25% WCGF (10%SG), 5% SG with 30% WCGF (5%SG), and 5% LG with 30% WCGF (5%LG). Animals were fed once daily at 0900 h using Calan head gates for an average of 155 d (heavy block = 148 d, light block = 162 d). Particle size of individual ingredients and treatment diets were quantified using the Penn State Particle Separator. Data were analyzed using the MIXED procedure of SAS with animal as the experimental unit. Means were separated using LSMEANS with the PDIFF option. There were no differences in final shrunk body weight ($P = 0.52$) between 5%SG, 5%LG, and 10%SG (1401, 1393, and 1373 ± 25.46 lbs, respectively), ADG (3.8, 3.8, and 3.7 ± 0.08 lbs, respectively; $P = 0.14$), or G:F (0.180, 0.175, and 0.176 ± 0.003, respectively; $P = 0.27$). However, DMI was greater ($P = 0.03$) for steers consuming the 5%LG diet compared to the 10%SG (21.9 and 21.0 ± 0.31 lbs, respectively). Dressing percent also was greater ($P = 0.05$) for steers consuming 5%LG compared to 5%SG and 10%SG (64.3, 63.1, and 62.5 ± 0.007%, respectively). Hot carcass weight tended ($P = 0.10$) to be greatest for steers fed 5%LG. Steers consuming 10%SG had the greatest daily minutes of rumination ($P < 0.001$) followed by 5%LG, and 5%SG being the least (310, 288, and 244 ± 2.98 min/d, respectively). Steers consuming a larger particle size had increased dry matter intake, hot carcass weight, and dressing percent. With similar roughage inclusion rate, steers consuming a larger particle size also had increased daily rumination minutes. Therefore, increasing roughage particle size has the potential to allow a decrease in roughage inclusion without sacrificing feedlot performance and rumen function.

Effects of Replacing Corn with a Pelleted Feed Consisting of Treated Corn Stover and Distillers By-Products on Total Tract Digestion and Performance of Finishing Cattle
J.L. Gramkow, M.L. Jolly-Breithaupt, C.J. Bittner, D.B. Burken, J.C. MacDonald, and G.E. Erickson, Univ. of Nebraska-Lincoln
Two studies evaluated the effects of replacing corn with a pellet containing alkaline treated corn stover, dry distillers grains, and solubles on total tract digestion and performance of finishing cattle. Experiment 1 utilized 4 ruminally fistulated steers (1425 lb BW; SD = 137) in a 4 x 6 Latin rectangle to evaluate the effects of replacing DRC with the pellet containing CaO treated corn stover and distillers by-products or components of the pellet on total tract digestion. Treatments consisted of a control (CON) containing 50.3% DRC, 40% modified distillers grains plus solubles (MDGS), and 5% stalks. The next 2 treatments replaced 25% DRC with either a CaO treated stover pellet (STOVPEL) or a CaO treated stover and distillers by-product pellet (COMBPEL). The last treatment replaced 25% DRC with a combination of the 10% treated stover pellet, 10% dry distillers grains plus solubles, and 5% solubles (COMB). Experiment 2 utilized 336 crossbred steer calves (initial BW = 663; SD = 55 lb) in a 2 x 3 plus 1 factorial design to evaluate the effects of replacing corn with the pellet containing CaO treated corn stover

and distillers by-products on performance. Factors were the inclusion level of MDGS (20 or 40%, DM basis) and the level of pellet inclusion (10, 20, or 30%, DM basis). The control diet (CON) contained a 50:50 blend of DRC and HMC and 40% MDGS. All diets contained 5% wheat straw and 4% dry meal supplement. In Exp. 1, no differences ($P \geq 0.50$) were observed between the CON, STOVPEL, COMB, or COMBPEL for DM (76.5, 75.4, 72.5, and 78.0%, respectively) or OM (79.1, 79.7, 75.7, and 80.5%, respectively) total tract digestibility. In Exp. 2, a linear increase ($P = 0.05$) in DMI was observed as pellet inclusion increased from 0% in the CON (23.30; SE = 0.28 lb/d) to 30% (24.16; SE = 0.28 lb/d) in diets containing 40% MDGS. A quadratic response ($P = 0.03$) in DMI was observed as pellet inclusion increased in diets containing 20% MDGS due to greater DMI of diets containing 20% pellet. A linear increase ($P = 0.04$) in F:G was observed as level of pellet increased from 0% (5.51; SE = 0.13) to 30% (5.73; SE = 0.13) in diets containing 40% MDGS. In diets containing 20% MDGS, no difference ($P \geq 0.22$) in F:G was observed as pellet inclusion increased from 10% to 30%. In conclusion, the pellet can replace up to 20% of corn in finishing diets when fed with 40% MDGS, and up to 10% in diets containing 20% MDGS without negatively impacting performance or digestibility.

Relationship between TDN and OM digested in beef cattle finishing diets *H. C. Hamilton, J. L. Harding, J. C. MacDonald, G. E. Erickson, T. J. Klopfenstein, and A. K. Watson, Univ. of Nebraska-Lincoln*

Organic matter digestibility (OMD) is related to TDN. However, the relationship is unestablished for diets containing byproducts. The addition of wet distillers grains plus solubles (DGS) increases feed efficiency but decreases OMD. Three cattle digestion studies were used to evaluate the relationship between TDN and OM digested. Total tract collection and OM analysis of feed and feces determined OMD which was multiplied by dietary OM content to determine OM digested (% of DM). Gross energy of feed and feces was determined by bomb calorimetry. Dietary DE was calculated and converted to TDN using 4.4 Mcal DE / kg TDN. Experiment 1 utilized 45% high moisture corn, 40% Sweet Bran, and 10% corn silage diets (DM basis); Experiment 2 used diets containing 40% modified DGS (DM basis) and increasing amounts of a corn stover pellet replacing dry rolled corn (DRC); Experiment 3 compared 80% DRC-based diets with corn oil or tallow to diets with 25.5% distillers solubles, or 56% wet DGS. Regression was used to relate OM digested to TDN. The initial model included experiment, animal within experiment, and treatment within experiment. A significant treatment within experiment effect ($P < 0.01$) resulted in independent regression models for each experiment. Experiment 1 and 2 showed no treatment effect and no interaction between treatment and OM digested, perhaps because they contained a constant concentration of byproduct. Therefore, a single slope with a linear relationship was used. In Experiment 3, different types and concentration of byproducts were used, and there was a tendency for a treatment effect ($P = 0.14$). Results from Experiment 1 indicate OM digested was 3.58 percentage units (ppt) greater than TDN content. In Experiment 2, OM digested was 11.1 ppt less than TDN content. In Experiment 3, OM digested in the corn diet was 3.96 ppt greater than TDN. For the tallow diet, OM digested was 0.34 ppt less than TDN, while in the corn oil diet, OM digested was 0.37 ppt greater than TDN. In the solubles and wet DGS diets, OM digested was less than TDN, 5.88 ppt and 9.96 ppt, respectively. The increase in ppt was consistent with an increase in gross energy (GE) across diets within experiment. These results suggest OM digested is consistent relative to TDN content of traditional, corn based diets. In finishing diets containing DGS, the additional DE supplied by DGS is not accounted for when evaluating only OM digested. This is likely due to the protein

and fat content of DGS, which supplies additional energy relative to its OM content. It is essential to measure DE content of diets used indigestion trials.

The effect of delayed corn silage harvest on performance of steers in growing and finishing rations *F. H. Hilscher[1], D.B. Burken, C.J. Bittner, J. L. Gramkow, R. G. Bondurant, T. J. Klopfenstein, and G. E. Erickson, Univ. of Nebraska-Lincoln*

Two experiments were conducted to determine the effect of delayed corn silage harvest in growing and finishing steers. Experiment 1 utilized 60 crossbred steers (BW = 597; SD = 70 lb) to evaluate the effects of harvesting corn silage at greater DM and response to rumen undegradable protein (RUP) supplementation. Treatments were arranged as a 2 × 5 factorial design. Factors included harvested corn silage DM (37 or 43%) and supplemental RUP inclusion (0.0, 2.5, 5, 7.5, or 10% of diet DM). Steers were individually fed using Calan gates and assigned randomly to treatment. No linear ($P \geq 0.33$) or quadratic ($P \geq 0.36$) interactions were observed between corn silage DM and supplemental RUP inclusion ($P \geq 0.22$) for growing performance. As DM of corn silage increased from 37 to 43%, there was a significant decrease ($P = 0.04$) in ending BW due to reduced ($P = 0.01$) ADG, which also increased ($P < 0.01$) F:G. Increasing supplemental RUP in the diet increased ($P \leq 0.05$) ending BW, DMI, and ADG linearly as supplemental RUP increased from 0 to 10%. With increases in both DMI and ADG, F:G decreased ($P < 0.01$) linearly as supplemental RUP inclusion increased. Experiment 2 utilized 180 crossbred yearling steers (BW = 943 ± 86 lbs) in a 108-d finishing trial to evaluate the effects of corn silage DM and replacing corn with corn silage in diets with 40% modified distillers grains with solubles. Factors were harvested corn silage dry matter (37 or 43%) and inclusion of corn silage in the finishing diet (15 or 45% of diet DM). On the day of harvest, HCW were recorded, and performance measures were calculated from HCW adjusted to a common dressing percentage (63%). There were no interactions between corn silage DM and inclusion of corn silage ($P \geq 0.47$) for feedlot performance or carcass characteristics. As inclusion of corn silage in the finishing diet increased from 15 to 45%, ADG decreased ($P = 0.04$) and F:G increased ($P < 0.01$). Carcass adjusted final BW and HCW were lower ($P \leq 0.04$) for steers fed 45% corn silage compared to 15%, but not live final BW (P = ?). There were no differences ($P \geq 0.26$) in LM area, 12th rib fat, and marbling score as corn silage inclusion increased. As DM of corn silage was increased from 37 to 43%, there were no differences ($P \geq 0.30$) in DMI, ADG, or F:G. Additionally, there were no differences ($P \geq 0.68$) in carcass adjusted final BW or HCW as corn silage DM was increased. No differences ($P \geq 0.27$) in 12th rib fat, or marbling scores were observed as DM of corn silage increased. Feeding silage in growing diets at 88% inclusion shows that 37% DM silage results in greater ADG and G:F compared to 43% corn silage. However, no there were no differences between 37% DM or 43% DM when fed at either 15 or 45% to finishing cattle. While increasing the inclusion of corn silage from 15 to 45% in place of corn in finishing diets reduces performance, delaying corn harvest and putting up drier corn silage in order to increase harvested corn silage tonnage could prove economical.

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Impact of feeding corn containing an alpha-amylase enzyme on finishing cattle performance and site of digestion *M. L. Jolly-Breithaupt, M. E. Harris, C. J. Bittner, F. H. Hilscher, J. L. Gramkow, B. L. Nuttelman, D. B. Burken, G. E. Erickson, J. C. MacDonald, and M. K. Luebbe, Univ. of Nebraska-Lincoln*

Four studies evaluated the effects of feeding corn containing an alpha-amylase enzyme trait (Syngenta Enhanced Feed Corn; SYT-EFC) on finishing performance, carcass characteristics, and site of digestion. Experiments 1 and 2 utilized 300 (657 ± 35 lb) and 240 calf fed steers (635 ± 33 lb), respectively, in a randomized block design with 10 steers per pen and 6 replications per treatment. Experiment 1 treatments were designed as a 2x2+1 factorial with factors being corn trait [SYT-EFC or commercial corn (CON)], byproduct [with and without Sweet Bran (SB)], and 50:50 blend of SYT-EFC and CON. Treatments for Exp. 2 consisted of SYT-EFC, CON, 50:50 blend of SYT-EFC and CON, and CON with an α-amylase enzyme supplement added (CON-E). In Exp. 3, 384 calf fed steers (686 ± 46 lb) were utilized in a randomized block design with 8 steers per pen and 6 replications per treatment. Treatments were designed as a 2x2x2 factorial with factors being corn trait [SYT-EFC and Negative Isoline Control (NEG); both corns were grown near Mead, NE], corn processing (dry rolled or high moisture corn), and byproduct (with and without Sweet Bran). Experiment 4, a 126-d metabolism trail was designed as a 6x4 Latin rectangle design with 6 periods and 4 ruminally and duodenally fistulated steers. Dietary treatments were similar to Exp. 1, however, NEG was utilized as the control corn. For Exp. 1, when fed with SB, SYT-EFC resulted in greater ADG and improved F:G ($P < 0.05$) compared to CON. Regardless of byproduct, SYT-EFC resulted in greater marbling score, 12th rib fat, and calculated yield grade ($P < 0.03$). For Exp. 2, steers fed SYT-EFC, Blend, and CON-E had greater FBW, ADG, F:G, and HCW than CON ($P < 0.03$). No 3 way interactions were observed for performance ($P > 0.34$) or carcass characteristics ($P > 0.21$) in Exp. 3. However, a corn processing*trait interaction was observed for final BW ($P = 0.02$) and ADG ($P = 0.04$) with steers fed SYT-EFC as DRC had the greatest FBW and ADG with SYT-EFC fed as HMC had the lowest. In Exp. 4, no interactions were observed for all starch digestibilities (P > 0.19). However, the main effect of corn trait was significant for postruminal ($P = 0.08$) and total tract ($P = 0.01$) starch digestibility. Steers fed SYT-EFC had greater postruminal and total tract starch digestibilities than steers fed NEG. Increased starch utilization of the SYT-EFC at the small intestine corresponding with the improvement in animal performance observed from steers fed SYT-EFC that contains the α-amylase enzyme trait.

Effects of *Saccharomyces cerevisiae* CNCM l-1077 supplementation on feeding behaviors and carcass traits on crossbred beef steers fed a concentrate diet *W. Kayser*, G.E. Carstens*, K. Barling†, M. Jenks*, A. Cupples*, J. Sawyer* and E. Chevaux†,* Texas A&M University, College Station, †Lallemand Animal Nutrition, Milwaukee, WI*

The aim of this study was to evaluate the effects of Levucell SC (*Saccharomyces cerevisiae* CNCM l-1077) supplementation on performance, feed efficiency, ruminal temperature, feeding behavior traits and carcass quality traits in yearling steers. Animals (N = 48) were sourced from Texas A&M University herds located at College Station and McGregor TX, which were of similar genetics (25% *Bos indicus*). The steers were blocked by source and initial BW (441 ± 30.8 kg), and assigned to 1 of 4 pens equipped with GrowSafe feed intake monitoring equipment. Pens were fed once a day either a yeast supplemented or control diet, neither diet contained tylosin or monensin. Animals were weighed on 14-d intervals, and feed intake and behavior data collected daily throughout the 70-d study using a GrowSafe 4000E (GrowSafe, Airedrie, AB)

system. Feed intake data quality was monitored daily, and data excluded if assigned feed disappearance was less than 0.90 for an individual scale or less than 0.95 for the pen on average. All analyses were performed using SAS (Cary, NC) and LS mean differences identified using the Proc Mixed procedure with pen replicate as a random effect. There were no differences amongst treatments in DMI, ADG, morbidity or mortality rates, ruminal temperature or F:G. Live-yeast supplemented steers had 17% greater (P = 0.05) backfat thickness than the control steers, which resulted in an 13% increase in yield grade, with no differences in all other carcass traits. Live-yeast supplemented steers exhibited different feeding behavior patterns than the control steers. The supplemented animals began eating on average 25 min earlier than the control, which resulted in a 41% (P = 0.001) reduction in time to bunk. The supplemented steers had 22% greater bunk visit (BV) duration (P = 0.02) and 41% increased head down duration (P = 0.03). The supplemented steers exhibited an 18% (P = 0.02) slower BV eating rate compared to controls. There was also less apparent variation in the diurnal pattern of BV eating rate in the live-yeast supplemented cattle. Additionally, there was tendency for live-yeast supplemented steers to have a 9% lower (P = 0.07) frequency of BV events. Live-yeast supplementation also resulted in distinctive differences in meal patterns. The behavioral patterns observed during meal events were similar to the BV events. Live-yeast supplemented steers displayed a 47% longer meal criterion (P = 0.01), which tended (P = 0.07) to reduce frequency of meals by 13%. Meals consumed by live-yeast supplement steers were 27% longer (P = 0.02) and tended to be 15% larger in size. During the 70-d study, live-yeast treatment decreased (P = 0.04) meal-eating rate by 10%. Even though there were large differences in feeding behavior patterns associated with BV and meal events, there were no differences in average DMI, or day-to-day variance in DMI throughout the study. Thus, the live-yeast supplemented steers approached the feed bunk sooner following feed delivery, ate larger, but fewer meals at a slower rate, and spent more time eating each day compared to the control cattle. Although there were no observed cases of ruminal acidosis or morbidity events during the study, live-yeast supplementation clearly altered feeding behavior patterns, which may have been the results of more favorable fermentation. These results suggest that live-yeast supplementation help mitigate metabolic stress in steers fed a high grain diet by altering their meal patterns.

Impact of rate of gain and days on feed during the growing phase on feed conversion during the finishing phase *H. Larson, and A. DiCostanzo, Univ.of Minnesota, St. Paul*
Feed, oil and biofuel prices, cattle inventories and beef supply, and supply of other meats affect cattle and feed prices. Manipulating cattle growth during growing periods post-weaning and pre-finishing may permit cattle feeders the opportunity to make relatively quick short-term changes thereby accommodating their capacity to respond to high grain prices and fluctuating cattle prices. Utilizing a meta-analysis approach we sought to understand effects of manipulating growth during a drylot or grazing pre-finishing phase on efficiency of feed conversion as gain to DMI or hot carcass weight to DMI. Data were derived from 32 manuscripts (20 drylot and 12 grazing studies) containing 158 treatment means. Measures of gain achieved by kg feed DM during the finishing phase and hot carcass weight resulting from finishing phase DMI were regressed on ADG and feeding period length (DOF) for the pre-finishing phase to determine the single and combined impact of rate of gain and pre-finishing period length (treatment means were weighed by experimental units per mean). Results from these regressions demonstrate that in a dry lot system fast rate of gain and short days on feed results in more saleable product efficiency but lowered rates of gain to feed ($p < 0.05$), while moderate rates of gain and short

days on feed resulted in increased gain to feed conversions but less efficiency in saleable product (HCW per unit intake) ($p < 0.05$). Within a dry lot system, as ME of the diet increased a significant increase in gain of HCW per unit of intake was observed ($p < 0.01$). In a grazing system, low rates of gain paired with long days of feed resulted in more efficient conversion of HCW per unit of intake than low gains paired with short days on feed ($p < 0.01$). Total dry matter intake was also reduced when grazing backgrounding system days on feed were shortened ($p < 0.01$). From these results, the conclusion that the effect of both days on feed and average daily gain during the backgrounding phase are what significantly correlate to improved finishing performance. Specifically, as gains increase during the backgrounding phase, the gains during finishing shift from compensatory type gain to a gain in saleable product.

Applying Reflective Pigment to the Dorsal Surface of Cattle to Reduce Heating by Sunlight
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Heat stress in feedlot cattle has serious animal welfare and economic implications. Environmental conditions including ambient temperature, humidity, wind, and solar radiation can affect heat load. While these factors are difficult to control, heat absorbed from solar radiation differs with surface characteristics such as shade or hide color. A reflective pigment on the hair coat may reflect solar energy and help mitigate heat stress in colored feedlot cattle. The pigment titanium dioxide is highly reflective and approved for use in feeds, food coloring, and sunscreens. The objective of this experiment was to determine if a titanium dioxide coating would reflect solar radiation off of cattle and mitigate heat stress. Feedlot heifers (n = 30, 29 black and 1 red; 591 lb +/- 60.8 lb) were used to evaluate a reflective coating containing titanium dioxide. Heifers were randomly assigned to control or coated treatments. The coating was applied to the dorsal midline with an electronic airless sprayer except for the area over the dorsal anterior midline, which served as a control. Reflectance from the dorsal surface was measured with a suspended modified digital camera. Hide surface temperature was measured with a suspended infrared thermal imaging sensor; adjacent panels of white, black, and grey provided reference temperatures. Vaginal thermometers attached to blank CIDRs were inserted into 6 heifers in each treatment to continuously record internal body temperature. Reflectance in the blue, green, and red color zones was found to be 5.7, 8.8, and 10.3 times greater ($P < 0.001$), respectively, for the coated areas than the uncoated. Dorsal surface temperature averaged 102.3 and 108.3^{o} F for coated and uncoated areas, respectively ($P < 0.001$). Reflectance values and hide surface temperatures suggest that solar energy was reflected rather than absorbed. Uncoated cattle had a 1.6^{o} F greater ($P < 0.01$) body temperature increase than coated cattle over a 2 to 3 h exposure to natural solar radiation on a day with a high ambient temperature of 101° F and a temperature humidity index of 87.8, which suggests that heat stress was reduced in coated cattle. A reflective coating applied to the dorsal midline of feedlot cattle shows potential to decrease heat absorbed and reduce heat stress.

Associations between metabolomic profiling and feeding behavior with residual feed intake for identification for potential biomarkers for RFI in feedlot cattle *M. D. Miller*, G. E. Carstens*, J. M. Thomson†, L. O. Tedeschi*, and P. K. Riggs* , * Texas A&M Univ., College Station,† Montana State Univ., Bozeman*
Objectives of this study were to evaluate the effects of residual feed intake (RFI) classification on performance, feed efficiency, and feeding behavior in steers fed a high grain diet, and to

examine associations between metabolite profiles and feeding behavior with RFI. Performance, dry matter intake (DMI) and feeding behavior traits were measured for 70 d in Angus crossbred steers (n = 168) using a GrowSafe system. RFI was computed as actual minus expected DMI derived from regression of DMI on ADG and mid-test $BW^{0.75}$. Steers were classified into low (n = 52), medium (n = 64), and high (n = 52) RFI groups based on ± 0.5 SD from the mean RFI of 0.00 (SD = 0.82). Low RFI steers consumed 17% less (P < 0.0001) DMI (9.05 vs 10.89 ± 0.14 kg/d) and had 18% lesser (P < 0.0001) F:G (5.05 vs 6.11 ± 0.10) than high RFI steers, but ADG was not different (1.78 ± 0.04). Steers with low RFI generated $95 per head more (P < 0.001) profit compared to high-RFI steers even though carcass value was not affected by RFI classification. Blood samples were collected from steers with lowest RFI (n = 25) and highest RFI (n = 24) on day 70 of the trial, and serum metabolite concentrations analyzed using ^{1}H-NMR spectroscopy. Partial least squares (PLS; MetaboAnalyst) were used to examine associations between RFI, and metabolites and feeding behavior traits. PLS was used instead of multiple linear regression, as PLS accounts for multi-collinearity of independent variables. Of the 12 feeding behavior traits evaluated, 4 traits had variable of importance in projection score (VIP) that were > 1.0, which included head-down (HD) duration, bunk visit (BV) duration, non-feeding interval (NFI) duration, and head-down to meal duration ratio (HD:MD). The first 2 components of PLS accounted for 54% of between-animal variance in RFI. Steers with low RFI had longer (P < 0.001) NFI duration (less time at the bunk), 45% lower HD duration, 35% lower BV duration, and 32% lower HD:MD ratio than high RFI steers. Of the 44 metabolites detected by ^{1}H-NMR, 5 metabolites had VIP scores > 2, which included glycine, betaine, tyrosine, valine, and leucine. The first 2 components of PLS accounted for 34% of between-animal variance in RFI. Steers with low RFI had higher (P < 0.001) concentrations of glycine, and lower (P < 0.06) concentrations of betaine, tyrosine, valine, and leucine than high-RFI steers. These preliminary results reveal that metabolomic profiling and feeding behavior may provide opportunities to identify biomarkers that are predictive of RFI in beef cattle. Further research is warranted to examine the repeatability and robustness of these biomarkers for prediction of RFI phenotypes in beef cattle.

Health evaluation of immune-stimulated and hay-supplemented feedlot receiving calves as assessed by blood gas analysis. *E.R. Oosthuysen[1], M.E. Hubbert[2], K.L. Samuelson[1], E.J. Scholljegerdes[1], G.C. Duff[1], and C.A. Löest[1], [1] New Mexico State University, Las Cruces, [2]Clayton Livestock Research Center-New Mexico State University, Clayton*
Innate immune stimulation and diet roughage level is believed to affect feedlot calf health associated with bovine respiratory disease. Blood oximetry is used in human medicine to diagnose pneumonia and has been correlated to arterial hypoxia in cattle. This study evaluated blood parameters, health, and performance of immune-stimulated and hay-supplemented feedlot receiving calves. A total of 705 South Texas crossbred heifers (394 ± 1.3 lb) were blocked by 6 truckloads and assigned to 48 pens and 4 treatments in a randomized complete block design. Calves did not receive metaphylactic antibiotics at initial processing. Treatments were a factorial arrangement of supplemental hay (+HAY vs -HAY) and DNA immune stimulation (+IMMUN vs -IMMUN). All calves were fed a feedlot receiving diet (Ramp), and those pens of calves assigned +HAY received supplemental alfalfa hay for the first 14 d. Calves assigned +IMMUN received a DNA immuno-stimulant (Zelnate) on d 0. On d 0, 14, and 28, individual BW, rectal temperatures, and venous blood samples (5 calves per pen) were collected. Health was recorded throughout the 56-day study, and pen weights were obtained on d 56. No HAY × IMMUN

interactions occurred ($P \geq 0.20$). During the first 14 d, calf ADG was greater (less negative; $P < 0.01$) for +HAY than –HAY (-0.68 vs -1.32 ± 0.17 lb/d), but d 14 to 28 ADG was lower ($P < 0.01$) for +HAY than –HAY (0.93 vs 2.15 ± 0.30 lb/d). Immune-stimulated (+IMMUN) calves had lower ($P \leq 0.01$) ADG than –IMMUN calves from d 28 to 56 (2.41 vs 2.83 ± 0.18 lb/d) and from d 0 to 56 (1.32 vs 1.57 ± 0.11 lb/d). Total DMI was greater ($P < 0.01$) for +HAY than –HAY from d 0 to 14 (5.89 vs 4.60 ± 0.18 lb/d), but lower ($P \leq 0.04$) from d 14 to 28 (7.92 vs 8.97 ± 0.26 lb/d) and from d 28 to 56 (11.67 vs 12.38 ± 0.30 lb/d). Gain efficiency (G:F) of +HAY calves was greater (less negative; $P < 0.01$) from d 0 to 14 (-0.127 vs -0.313 ± 0.042), but lower ($P < 0.01$) from d 14 to 28 (0.111 vs 0.240 ± 0.036) when compared to -HAY. Gain efficiency (G:F) was lower ($P \leq 0.02$) for +IMMUN than –IMMUN calves from d 28 to 56 (0.207 vs 0.229 ± 0.012) and d 0 to 56 (0.142 vs 0.166 ± 0.010). Calf morbidity, mortality, and blood parameters (pH, glucose, lactate, and hemoglobin saturated with oxygen [sO_2]) were not affected ($P \geq 0.20$) by hay supplementation or immune stimulation. Blood sO_2 was lower ($P < 0.01$) on d 0 than d 14 and 28 (60.0 vs 65.6 and 64.2 ± 0.99%), and glucose was greater ($P < 0.01$) on d 28 than d 0 and 14 (102.3 vs 96.3 and 95.5 ± 1.84 mg/dL). Blood pH was correlated ($P < 0.05$) with sO_2 ($R^2 = 0.39$), glucose ($R^2 = -0.33$), lactate ($R^2 = -0.60$), and first ($R^2 = 0.09$) and second ($R^2 = -0.08$) medical treatment. Blood sO_2 was correlated ($P < 0.05$) with glucose ($R^2 = 0.09$), lactate ($R^2 = -0.12$) and mortality ($R^2 = 0.08$). Glucose correlated with lactate ($R^2 = 0.61$), and first ($R^2 = -0.22$) and second ($R^2 = -0.13$) medical treatment. Lactate was correlated ($P < 0.05$) with first medical treatment ($R^2 = -0.12$) and mortality ($R^2 = -0.12$). In conclusion, hay supplementation and immune stimulation did not affect calf health, performance or blood gas parameters. Correlations between blood parameters and animal health suggest possible application as a diagnostic tool.

The Relationship between Crop Water Use and Finishing Performance of Beef Steers Fed Diets Containing Corn or Sorghum Distillers Grains *T. L. Opheim, C. E. Carpio, C. P. West, D. M. Mitchell, P. N. Johnson, and S. J. Trojan, Texas Tech Univ., Lubbock*

Feedlot steers were fed diets containing 25% (DM basis) corn dried, sorghum dried, or sorghum wet distillers grains with solubles (DGS) in a previously conducted study, with G:F for corn DGS = 0.153, and sorghum wet DGS = 0.150, and sorghum dried DGS = 0.142. These G:F ratios were combined with crop yield and crop water (effective precipitation, irrigation, and soil moisture) data collected over a 10-yr period by the Texas Alliance for Water Conservation project (Hale and Floyd counties in southern Texas High Plains region) to develop an equation for water use efficiency of beef production. The relationships between crop yield and crop water use was determined using quadratic regressions. Crop yield-to-water ratios (kg/ha-m^3) were then calculated using predicted yields. Distillers grain-to-water ratios were calculated using a grain to DGS conversion factor (GDG). To account for crop water requirement of the DGS portion of the grain, total crop water was multiplied by 0.33. The DGS:water ratio was adjusted for the DM of DGS source, yielding a value expressed in kg of DGS/m^3 of crop water. The DGS contribution (DC) to NE_g was accounted for, and G:F was adjusted to reflect kg of beef gain from DGS. The DGS G:F was divided by the DGS:water ratio to determine the water use efficiency of beef production as kg of beef/m^3 crop water. Water Use Efficiency of Beef Production = $\{(DC\%)x\ G{:}F\} \div \left[\left\{\left(\frac{kg\ Grain}{m^3\ Water\ x\ 0.33}\right) \div GDG\right\} \times DGS\ DM\right]$. Overall, corn had greater crop water requirements than grain sorghum; however, grain sorghum yields were greater at lower water inputs than corn. The critical crossover point between corn and grain sorghum was approximately 366 millimeters of crop water and 6854 kg grain/ha; indicating a water and yield

trade-off. At a water application of 197 mm, an optimum water use efficiency was reached at 0.083 kg/m^3 for sorghum wet DGS and 0.068 kg/m^3 for sorghum dried DGS. Corn DGS reached its peak efficiency at 514 mm of crop water, with a water use efficiency of 0.074 kg/m^3. Although corn DGS reached a greater peak efficiency, sorghum DGS more efficiently produced beef at water inputs reflective of dryland conditions. This analysis is a novel example of an approach for combining crop water use and beef performance. As crop irrigation restrictions affect the Texas High Plains and measuring sustainability of beef production advances, evaluating tradeoffs of resource utilization and production will continue to be important.

Effect of live yeast fed to natural-program beef steers during the finishing phase

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Growth performance, carcass characteristics, nutrient digestibility, and feeding behavior were evaluated in natural-program beef cattle fed steam-flaked corn-based finishing diets with 3 inclusion levels of live yeast (ABVista Inc., UK: 0, 25, and 50 g/steer daily). Steers (n = 144; 751 ± 45 lb) were blocked by BW and randomly assigned to treatments in a randomized complete block experimental design. The natural program did not include the use of implants, ionophores, and antibiotics. Live yeast was included in a premix (cottonseed meal carrier) at 1% of the diet (DM basis). Data were analyzed using the GLIMMIX procedure of SAS with pen used as the experimental unit. Feed efficiency tended to be improved (quadratic, $P = 0.08$) between d 0 to 183, with steers fed 25 g/d of live yeast having a 4.3% greater G:F than the average of other treatments. Linear increases in premium Choice ($P < 0.01$) and Choice ($P = 0.05$) carcasses were observed as live yeast increased in the diet. Total tract nutrient digestibility increased (quadratic, $P < 0.01$) as live yeast increased, with steers fed 25 g/d having greater digestible DM (5.4 %), organic matter (4.8 %), NDF (22.1 %), ADF (19.9 %), hemicellulose (22.7 %), crude protein (6.2 %), and ether extract (2.5 %) than the average of steers in the other treatments. Rumination (11%), eating time (8%), and chewing activity (20%) were not affected by treatments (% of 24 h evaluation). Live yeast included at 25 g/d in the finishing diet of natural-program beef steers improved dietary nutrient digestibility (except starch), carcass quality grade, and tended to improve animal efficiency, without affecting feeding behavior.

Red grape pomace to adapt beef cattle to finishing diets and spoilage mitigation strategies

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The effects of red grape pomace to step-up beef steers to steam-flaked corn-based finishing diets on growth performance, carcass characteristics, nutrient digestibility, feeding behavior, and mitigation of pomace spoilage were evaluated. In study 1, Crossbred yearling steers (n = 48; 803 ± 114 lb) were blocked by BW and randomly assigned to 1 of 2 adaptation strategies: 1) traditional roughage sources (alfalfa hay/cottonseed hulls-based), and 2) red grape pomace-based, in a randomized complete block design. Both adaptation strategies decreased roughage ingredients as steam-flaked corn gradually increased in the diets. Steers were fed once daily a series of 5 diets consisting of 4, 7-d step-up and 1 common finishing diet (160 d), which did not contain pomace. In study 2, red and white grape pomace were ensiled (5ga units, n = 6 per treatment), following 1 of the 4 spoilage mitigation strategies: a) control; b) molasses; c) inoculant (*L. buchnery*), and d) inoculant + molasses in a completely randomized design (2 x 4 factorial treatment arrangement). Data were analyzed using the GLIMMIX procedure of SAS.

Intake, gain, and efficiency of steers during either adaptation or finishing phases were not ($P \geq 0.16$) negatively affected by red grape pomace when compared to traditional adaptation strategy. Total tract apparent digestibility of DM, OM, EE, NDF, and ADF evaluated during finishing phase was not ($P \geq 0.53$) affected by adaptation strategies, except by a subtle (99.46 vs. 99.03 %) increase ($P = 0.01$) in starch digestibility for steers fed pomace when compared to traditional adaptation strategy, respectively. Feeding behavior was not ($P \geq 0.21$) affected by adaptation strategies, except by steers fed traditional strategy spending 17.3 and 18.4 % more time ruminating and chewing on step-up diet 3, compared to pomace strategy in the same phase ($P = 0.04$ and $P = 0.01$, respectively). After storage period (169 d), red grape pomace lost less DM compared to white pomace (7.87 and 11.37 %, respectively; $P < 0.03$), while no differences among mitigation treatments were observed ($P = 0.52$). Red grape pomace strategy adapted beef steers to finishing diets without detrimental effects on growth performance and nutrient digestion when compared to traditional alfalfa hay/cottonseed hulls approach. Grape pomace can be stored for long periods under anaerobic conditions, however methods to mitigate spoilage must be further studied.

Effect of castration method and analgesia on performance and welfare measures in feedlot cattle *S.L. Roberts[1], H.D. Hughes[1], J.G. Powell[2] and J.T. Richeson[1], [1]West Texas A&M Univ., Canyon, [2] Univ. of Arkansas, Fayetteville*

There is little agreement on the best castration method; a recent USDA survey reported 52.3 and 41.1% of bulls are surgically and band castrated, respectively, upon feedlot arrival and analgesia may mitigate inflammatory pain associated with either method. The objective of this study was to determine the effect of castration timing (birth vs. feedlot entry), method (surgical vs. banding) and use of the analgesic meloxicam (MEL) on growth and carcass performance, behavior, and inflammation in feedlot cattle. This study was a randomized block design conducted over a three-year period. Angus × Hereford calves (steers n = 42; bulls n = 152) were randomized at birth to 1 of 5 treatments arranged as a 2 × 2 + 1 factorial: 1) negative control animals castrated near birth (CON), 2) bulls surgically castrated without MEL (SUR), 3) bulls surgically castrated with MEL (SUR+MEL), 4) bulls band castrated without MEL (BAN), and 5) bulls band castrated with MEL (BAN+MEL). Upon feedlot arrival (d -10), animals were blocked by BW and assigned randomly to treatment pens (n = 6 pens/ treatment). Oral MEL was administered at 1 mg/kg of BW concurrent with castration on d 0. Individual BW was collected periodically during the receiving and finishing period to determine ADG. Blood samples were collected on a subset of animals (n = 5 animals/pen) on d 0, 0.25, 1, 4, 7, and 14 and serum was harvested to determine haptoglobin (Hp) concentration as a proxy for inflammation. On d -10, accelerometers were placed on the same subset of cattle to determine baseline and post-castration changes in behavior data indicative of pain; the activity variables (standing, steps, lying bouts, motion index) were continuously logged and averaged by d. There was an improvement in overall ADG ($P = 0.04$) for CON compared to castrated treatments and MEL improved ($P < 0.01$) overall ADG. Control animals had increased marbling score ($P = 0.03$) compared to castrates; whereas, backfat thickness was greater ($P < 0.05$) in SUR+M, but did not differ from CON ($P = 0.15$). There was a treatment x day interaction ($P = 0.04$) with SUR animals having the greatest ($P < 0.01$) concentration of Hp on both d 1 and 4. Meloxicam administered during surgical castration was able to reduce ($P = 0.01$) Hp concentration relative to SUR on d 1. Method of castration had contrasting effects on specific behavior variables. The surgically castrated animals spent more time standing ($P < 0.01$) immediately following castration (d 0),

while the banded animals had a greater number of lying bouts ($P < 0.01$). Castration near birth had long-term performance and welfare benefits compared to castration upon feedlot arrival. Meloxicam mitigated the more pronounced inflammation observed in surgically castrated bulls and improved ADG for either castration method.

Does excess dietary protein impact performance and carcass characteristics of crossbred finishing heifers consuming ractopamine hydrochloride? *K. L. Samuelson, M. E. Hubbert, E. R. Oosthuysen, Z. Bester, and C. A. Löest, Clayton Livestock Research Center-New Mexico State Univ., Clayton*

High amounts of byproducts in finishing cattle diets results in an excess supply of dietary protein, which may influence animal performance because of metabolic costs associated with ammonia detoxification. Beta-agonists increase animal performance, thus potentially increasing CP requirements and reducing ammonia detoxification. This study evaluated if excess dietary CP decreases performance and carcass quality of finishing cattle fed diets with or without ractopamine hydrochloride (RH). Heifers (525) were assigned to 48 pens in a randomized complete block design (4 blocks, 12 pens per block). Within block, pens of cattle were randomly assigned to 3 protein and 2 RH (0 vs 400 mg/day) treatments. Protein treatments were steam-flaked corn-based diets containing 13.9% CP, 8.8% RDP, and 5.0% RUP (CON), 20.9% CP, 13.4% RDP, 6.1% RUP (DIP), or 20.9% CP, 9.1% RDP, 10.4% RUP (UIP). Cattle were weighed at initiation of RH (35 d before harvest; 1184 ± 10 lb) and at shipping. No RH × CP interactions ($P \geq 0.11$) occurred for performance or carcass traits. Excess CP did not affect ($P \geq 0.12$) final BW (1270 ± 11 lb) or ADG (2.48 ± 0.07 lb). However, both carcass-adjusted (adj.) final BW (1265, 1273, and 1263 ± 4 lb for CON, DIP, and UIP) and adj. ADG (2.33, 2.54, and 2.26 ± 0.11 lb for CON, DIP, and UIP) tended to be greater ($P = 0.06$) for cattle receiving DIP than UIP and CON. Water intake (8.5 ± 0.2 gal), DMI (20.1 ± 0.2 lb), F:G (8.1) and adj. F:G (8.4) were not different ($P \geq 0.12$) among CP treatments. Hot carcass weight (810, 814, and 808 ± 2.6 lb for CON, DIP, and UIP) tended to be greater ($P = 0.06$) for cattle receiving DIP than UIP and CON. Dressing % (63.9, 64.1, and 63.5 ± 0.13% CON, DIP, and UIP) was lower ($P < 0.01$) for cattle fed UIP than DIP and CON. Marbling score (43 ± 0.4), back fat depth (0.62 ± 0.02 in), ribeye area (14.4 ± 0.1 in^2), and yield grade (2.5 ± 0.1) were not different ($P \geq 0.16$) among CP treatments. Heifers receiving UIP tended to have lower ($P = 0.10$) KPH fat (3.32, 3.24, and 3.10 ± 0.13% for CON, DIP, and UIP) than CON. Percentage choice (50, 56, and 44 ± 3.9% for CON, DIP, and UIP) tended to be greater ($P = 0.09$) for heifers receiving DIP vs. UIP. Water and DMI were not different ($P \geq 0.36$) for RH vs. no RH. Cattle receiving RH had greater ($P < 0.01$) final BW (1282 vs. 1258 ± 3.6 lb), adj. final BW (1282 vs. 1252 ± 3.6 lb), ADG (2.81 vs. 2.11 ± 0.10 lb), and adj. ADG (2.80 vs. 1.96 ± 0.10 lb), and lower ($P < 0.01$) F:G (7.13 vs. 9.58) and adj. F:G (7.17 vs. 10.38) compared with no RH. Hot carcass weights (820 vs. 801 ± 2.3 lb) were greater ($P < 0.01$) and dressing % (64.0 vs. 63.7 ± 0.11%) tended to be greater ($P = 0.09$) for cattle receiving RH, while marbling score was not affected ($P = 0.11$) by RH treatment. Back fat depth (0.60 vs. 0.64 ± 0.03 in) tended to be lower ($P = 0.08$), and KPH fat (3.13 vs. 3.31 ± 0.12) was lower ($P = 0.02$) for cattle receiving RH vs. no RH. Ribeye area (14.5 vs. 14.2 ± 0.12 in^2) was greater ($P = 0.03$) for cattle receiving RH vs. no RH. No difference ($P \geq 0.14$) was observed in yield grade or percentage choice (50 ± 2.4%) for RH compared to no RH. Liver abscesses (7.1 ± 0.97%) were not different ($P \geq 0.14$) among RH and CP treatments. Excess CP does not negatively impact performance or carcass traits of finishing cattle, and no interactions between CP and RH suggest that CP requirements are not affected by RH.


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Dose response effect of NutriTek® on leukocyte functionality during a dexamethasone challenge in Holsteins steer calves *K.P. Sharon[1,3], Y. Liang[1], R.E. Hudson[1], I. Yoon[2], M.F. Scott[2], N.C Burdick Sanchez[3], P.R. Broadway[3], J.A. Carroll[3], and M.A. Ballou[1*], [1]Texas Tech Univ., Lubbock, [2]Diamond V Mills, Inc., Cedar Rapids, IA, [3]USDA-ARS, Livestock Issues Research Unit, Lubbock*
The objective of this study was to determine the dose response effects of supplementing NutriTek® on leukocyte functionality and *ex vivo* cytokine production during a dexamethasone (DEX) challenge. Holstein steers (125.1±8.16kg; N=32) were assigned to treatments including 0, 20, 40, or 60g/head/d of NutriTek® (n=8). Calves were housed in open, dry lot corrals with 4 calves per pen (2 pens/treatment). Calves were offered *ad libitum* access to a 50/50 total mixed ration of a commercially available 16% crude protein pelleted calf grower and chopped alfalfa hay. Treatments were top dressed for 21d. Orts were measured daily and the quantity of feed was adjusted for approximately 10% orts. After the 21d adjustment to diets, calves were jugularly catheterized and moved into individual stations (2.13×0.76 m) in an environmentally controlled barn and allowed 48h to adapt before the first DEX injection. Blood samples were collected at -24, -6, 0, 6, 12, 18, 24, 48, and 72h relative to the first DEX injection. DEX was administered via jugular catheter at 0.1 mg/kg BW at 0, 6, and 12h. Peripheral blood neutrophil (PMN) concentrations increased ($P<0.001$) at 6h and remained elevated through 72h in all steers. PMN L-selectin and PMN and monocyte (MONO) oxidative burst (OB) and phagocytosis (PHAG) of an environmental *Escherichia coli* decreased ($P\leq0.059$) at 6h in all steers. L-selectin returned to baseline at 72h while OB and PHAG failed to return to baseline by 72h. Total leukocytes counts ($P<0.001$) and PMN concentrations ($P=0.001$) increased linearly with NutriTek® dose. PMN L-selectin concentrations did not differ ($P=0.684$) among treatments. Oxidative burst intensity in PMN ($P=0.025$) and MONO ($P=0.003$) increased linearly with NutriTek® dose at 72h, as well as in MONO PHAG intensity ($P=0.004$) at 6 h. The percentage of PMN ($P=0.012$) and MONO ($P=0.013$) that were both PHAG and OB linearly increased with NutriTek® dose at 72h. *Ex vivo* whole blood lipopolysaccharide stimulated TNF-α concentrations tended to be greater ($P=0.026$) in NutriTek® steers than control steers at -24h. *Ex vivo* IFN-γ production did not differ ($P=0.695$). Overall, these data demonstrate that the dexamethasone challenge induced severe leukocyte dysfunction, and NutriTek® supplementation influenced plasma neutrophil concentrations and may have increased recovery of neutrophil and monocyte function.

A survey to describe current feedlot cattle facilities in the United States *J.C. Simroth*, D.U. Thomson*[1], E.F. Schwandt*, S.J. Bartle*, C.K. Larson‡, C.D. Reinhardt**
** Kansas State Univ., Manhattan, ‡ Zinpro Corp., Eden Prairie, MN*
Feedlot managers (n = 43) participated in a survey to obtain a current description of outdoor cattle feeding facilities in the U.S. Participants answered questions on general feedlot information, shipping and receiving areas, finishing pens, and hospital areas. Feedlots had one-time capacities of: < 10,000 animals (21%); 10,000 to 20,000 animals (26%); and >20,000 animals (53%). Cattle gathering facility design and equipment utilized in the processing barn consisted primarily of crowding tubs (74%) and Bud Boxes (19%) or a combination of a tub and terret gates (3%). Pen space of 100 ft^2/animal for receiving cattle is provided by most feedlots (55%), 150 to 200 ft^2/animal for calves at elevated risk of respiratory disease is provided by 68% of feedlots, and finishing cattle are provided 101 to 250 ft^2/animal of pen space by 66% of feedlots. Fifty percent of participating feedlots provide bunk space of 9 to 12 in/animal for calves at elevated risk of respiratory disease and a bunk space of 10 to 12 in/animal is provided by 55%

of feedlots for finishing cattle. Twenty-seven percent of feedlots allow 3 to 6 in/animal of linear water tank space for finishing cattle. Windbreaks are used in finishing pens by 43% of the feedlots and mounds were reported in 71% of finishing pens of feedlots surveyed. All feedlots reported concrete aprons adjacent to the feed bunk. Fewer feedlots (17%) provided shade for cattle in feeding pens although a greater percentage (50%) provided shade in the hospital pens. Dedicated health treatment facilities that were distinct from the post-arrival processing facility were reported in 66% of feedlots surveyed. These data benchmark outdoor cattle feeding facilities utilized in the High Plains of the United States.

Development of predictive algorithms for preclinical detection of bovine respiratory disease based on deviations in feeding behavior patterns in *cattle* *P.S. Smith[1], K.S. Jackson[1], W. Kayser[1], Y. Fu, A. Banerjee[1], L.O. Tedeschi[1], W.E. Pinchak[2], J. Wall[1], and G.E. Carstens[1]*
[1]Texas A&M Univ., College Station ,[2]Texas A&M AgriLife Research, Vernon
Current methods used for BRD detection rely on subjective assessments of clinical symptoms by pen riders, which have marginal diagnostic sensitivity and specificity. Alterations in behavioral patterns associated with feed consumption are among the earliest indicators of morbidity in cattle, and previous research has shown that BRD could be detected 3 to 4 d prior to clinical signs using electronic bunk-visit attendance data. Objectives for this study were to examine the use statistical process control (SPC) procedures to objectively evaluate deviations in DMI, and multiple feeding behavioral traits relative to the onset of BRD. Commercial seedstock bulls (N = 236), previously vaccinated against standard viral and bacterial pathogens, were used in this study. During a 10-d period beginning on day 28 of the trial, 30 bulls were treated for clinical symptoms of BRD (Rectal temperatures ≥ 39.7^{o}C). Thereafter, in response to a 50% reduction in DM intake, metaphylaxis treatment was administered to all remaining bulls (N = 201) on day 38 of the trial. Daily DMI and feeding behavior traits (frequency and duration of bunk visit (BV) events, head-down (HD) duration, maximal and variance of non-feeding intervals (NFI), time to approach feed bunk following feed-truck delivery; TTB) were measured for 70 d with a GrowSafe® system. For each trait, SPC models using CUSUM charts were computed for each animal in a daily iterative manner for Period 1 (0 to 38 d) when animals were deemed clinically ill and Period 2 (42 to 69 d) when animals were deemed healthy. SPC models were applied separately to the clinically-ill and metaphylactically-treated cohorts. Day of electronic BRD detection was based on CUSUM values exceeding lower or upper control lines, and differences from day of observed clinical illness (Cohort 1) or metaphylaxis treatment (Cohort 2) analyzed using t-tests. Model accuracy of the SPC models was based upon the proportion of true positives in period 1 and the proportion of true negatives in period 2 divided by the total number of observations. In both cohorts, DMI, BV traits, and HD duration decreased prior to clinical illness, whereas TTB, eating rate, and NFI traits increased prior to clinical illness. In the clinically-ill cohort, SPC-model detection based on BV and HD duration occurred ($P < 0.05$) 2.7 and 3.0 d prior to observed clinical illness, with model accuracies of 87 and 89%, respectfully. SPC-model detection based on eating rate yielded ($P < 0.05$) the earliest day of detection at 6.4 d prior to observed clinical illness, with model accuracy of 77%. DMI had the highest proportion of true positives of all traits analyzed, but day of detection was not different from day of observed clinical illness. Additionally, SPC models based on BV frequency, TTB, and NFI traits were not significantly different from the day of observed clinical illness. In the 2-behavior trait SPC model, time of detection was 2.5 d prior to observed clinical illness, with model accuracy of 92%. In the metaphylaxis-treated cohort, SPC models based on DMI had the highest accuracy

(84%) with day of detection 3 d prior to metaphylaxis treatment. SPC models based on feeding behavior traits were able to detect clinical illness 3.2 to 9.6 d prior to metaphylaxis treatment. The 2-behavior trait SPC model detected clinical illness 6.5 d prior to metaphylaxis treatment and had the highest proportion true positives (68%). However, the proportion of true positives and model accuracy was lower compared to the clinically-ill cohort, which may be attributed to the animals being in various stages of the disease process at the time of metaphylaxis treatment. These results demonstrate the potential value of electronic behavior-monitoring systems for accurate real-time preclinical detection of BRD in feedlot cattle.

The effect of chromium propionate supplementation on live performance and serum urea-N concentrations following a combined trenbolone acetate/estradiol benzoate implant in yearling feedlot steers *Z.K. Smith[1], J.O. Baggerman[1], A.J. Thompson[1], W. Rounds[2], and B.J. Johnson[1], [1]Texas Tech Univ., Lubbock, TX, [2]Kemin Industries, Des Moines, IA*
To date, no research has evaluated the influence of increasing concentrations of supplemental chromium from chromium propionate (KemTRACE® Chromium 0.04%, CrP, Kemin Industries, Des Moines, IA) on growth performance or changes in serum urea-N (SUN) following a 100 mg TBA/14 mg EB implant (SYNOVEX CHOICE®, Zoetis, Florham Park, NJ). In this study, the animal model used was yearling feedlot steers (n=32; initial BW=808 ± 37 lb), that were showing signs of maturity. The 4 dietary treatments included: 0 ppb (CON); 150 ppb (LOW); 300 ppb (MED); or 450 ppb (HIGH) added CrP to the diet. A steam flaked corn finishing diet that included vitamins and minerals to meet or exceed NRC requirements (NRC, 1996), and monensin (34 g/T), was fed 1X daily offering *ad libitum* access to feed in a clean bunk management system. Data were analyzed using the mixed procedure of SAS® (SAS Institute Inc., Cary, NC) as a RBD with the main effect of diet, while block was included as a random variable. Pen (n=4/diet) served as the experimental unit for live performance and steer (n=8/diet) served as the experimental unit for SUN measurements. Pre-planned contrasts that evaluated the effect of CON vs. CrP, as well as linear and quadratic contrasts were used. Significant observations were discussed ($P \leq 0.10$), and trends were discussed ($P \leq 0.15$ to $P \geq 0.10$). Body weight measurements and blood collection occurred in the morning (0800h) at treatment initiation and on d 28 prior to feed delivery. The addition of CrP tended to linearly increase d 28 BW (P=0.11) and ADG (P=0.14). Cattle fed CON had a 5% reduction (P=0.06) in DMI relative to CrP (15.47 vs. 16.23 ±0.374). Increasing concentrations of CrP linearly increased (P=0.02) DMI. Although not statistically different, there was an 8% improvement in F/G for CrP over CON. At treatment initiation, SUN concentrations were similar (P=0.30) between diets. On d 28 a quadratic effect (P=0.06) for SUN was detected. Generally, as an indicator of anabolism values of SUN on a given day are not as valuable as changes in SUN following anabolic stimulation. Thus, changes in circulating concentrations of SUN were calculated as (ΔSUN= d28 SUN-initial SUN). A quadratic effect (P=0.01) on ΔSUN was detected. Cattle fed HIGH had the greatest depression in SUN, cattle fed CON were intermediate and cattle fed LOW or MED actually increased SUN at 28 d post-implant. These data indicated that added CrP stimulated ADG and DMI in the 28 d period following an implant. The quadratic effect of CrP on ΔSUN could be explained by the fact that there was a dose-dependent response to increasing CrP in yearling feedlot steers. Insulin is critical for amino acid uptake to support lean tissue accretion. Cattle fed CON were likely the least sensitive to endogenous insulin and behind on lean tissue accretion, cattle fed LOW and MED were more sensitive to endogenous insulin and potentially maxed out on lean accretion, and cattle fed HIGH benefited from the additional intake of CrP resulting in

the greatest depression of SUN at 28 d post-implant. It is recommended to feed at least 450 ppb of added Cr as CrP to the diet in yearling feedlot cattle showing obvious signs of maturity to improve feedlot performance.

Comparison of the effects of laidlomycin propionate plus chlortetracycline vs. monensin plus tylosin and multiple beta-agonist feeding strategies on feedlot performance and carcass characteristics *A. J. Thompson*, Z. K. F. Smith*, M. Corbin†, L. B. Harper†, and B. J. Johnson*, *Texas Tech Univ., Lubbock, †Zoetis, Florham Park, NJ*
One hundred ninety-two steers (Initial BW = 781 ± 50.1 lbs.) were used in a randomized complete block design to examine the effect of various ionophore and ractopamine hydrochloride (RH) supplementation strategies on performance and carcass characteristics. Twelve pens of four steers were assigned to each of the following treatments: control (CON; no ionophore, antimicrobial or beta-agonist), laidlomycin propionate plus chlortetracycline with or without RH (LP and LPRH, respectively), and monensin plus tylosin with RH (MON). Steers were fed for a total of 151 d, of which RH supplemented treatments received the beta-agonist for the final 32 d. Laidlomycin propionate and chlortetracycline were removed during this period for the LPRH treatment, as no current combination clearance exists for the commercially applied beta-agonist (Actogain; Zoetis LLC, Florham Park, NJ). When included in the diet, laidlomycin propionate, chlortetracycline, monensin, tylosin, and RH were supplemented at 10.7 g/ton, 343 mg/(head · d), 32.0 g/ton, 10.7 g/ton, and 255 mg/(head · d) (DM basis), respectively. Upon harvest, carcass data was collected by trained personnel. Prior to RH supplementation (d 0 to 118), both LP and LPRH treatments had improved ADG ($P < 0.02$) and F:G ($P < 0.01$) over CON, while MON was intermediate. During the RH supplementation period (d 119 to 150), LP maintained greater DMI ($P < 0.01$) than both RH treatments; however, over the same period, MON treated cattle had reduced F:G ($P < 0.02$) compared to LP supplemented cattle and unsupplemented controls. Feeding LP without RH increased final BW ($P = 0.02$) over CON, and all ionophore supplemented treatments had improved ADG ($P < 0.05$) and F:G ($P < 0.05$) over the entire 151 d feeding period. Hot carcass weight was significantly greater ($P = 0.04$) in cattle fed LP with no beta-agonist than CON, where LP cattle yielded an average of 26 lbs. more HCW, while both RH supplemented treatments were intermediate. Monensin plus tylosin with RH yielded significantly greater LM area ($P = 0.03$) than unsupplemented controls; however LP and LPRH treatments were unaffected. All other carcass characteristics were not significantly different. The results of this study indicate that LP supplementation alone without the use of a beta-agonist may yield similar live performance and carcass responses associated with the administration of RH. These results also suggest that performance and carcass characteristics for cattle fed laidlomycin propionate plus chlortetracycline are similar to those of cattle fed monensin plus tylosin throughout the entire feeding period.

Effects of dietary energy concentration and intake on ruminal pH during various phases of adaptation *L. A. Trubenbach, T. A. Wickersham , J. R. Baber, and J. E. Sawyer, Texas A&M Univ., College Station*
Highly fermentable diets may cause ruminal acid accumulation leading to subacute ruminal acidosis (SARA), especially upon transition from forage- to concentrate-based diets. Intake restriction reduces acid accumulation, suggesting that intake limits may exist to reduce SARA risk without prolonged adaption. Six ruminally cannulated steers were used in a 6×6 Latin square designed to evaluate effects of energy concentration and intake on ruminal pH during transition,

following adaptation, and upon return to a forage diet. Three diets providing 1.580 Mcal NE_m/kg (32% corn), 1.825 Mcal NE_m/kg (48% corn), or 2.070 Mcal NE_m/kg (64% corn) were fed to meet NE requirements (NRC, 2000) for either a 454-kg mature, dry, open cow at maintenance (LOW), or a 390-kg primiparous cow at 6.09 kg/d lactation, gaining 0.14 kg/d (HIGH) in a 3×2 factorial arrangement. Steers were abruptly switched from hay to treatment diets to initiate each 14-d period. Transition responses were determined on d 1 and 2 (0, 2, 4, 6, 9, and 12 h post feeding); adapted responses on d 10 (0 2, 4, 6, 9, and 12 h after feeding); and hay diet data on d 11-14 (0 and 4 h after feeding) of each period. By 2 h after feeding on d 1, pH was lower ($P < 0.01$) in HIGH (6.47) than LOW (6.69); this effect was sustained through the first 36 h of treatment application ($P < 0.01$). After 10 d of adaptation, mean pH was lower ($P < 0.01$) in HIGH (6.08) than LOW (6.58). Mean pH decreased linearly ($P < 0.01$) with an increase of corn inclusion in HIGH (6.22 to 5.93), and tended to follow the same pattern in LOW ($P = 0.07$; 6.64 to 6.51). Time under pH 5.6 and 6.0 was greater for HIGH ($P < 0.01$), and increased linearly ($P < 0.01$) with corn inclusion in HIGH (115.43–293.62 and 496.55–788.82 min, respectively), but not in LOW ($P > 0.78$). Area (min×pH/d) under pH 5.6 and 6.0 was greater ($P < 0.01$) in HIGH than LOW, and increased linearly ($P < 0.01$) with corn inclusion in HIGH (7.91 – 53.28 and 138.25–265.98 min×pH/d, respectively), but not LOW ($P > 0.78$). One d after returning to forage diets, pH collected 4 h post-feeding ranged from 6.5 to 7.0 across treatments with minimal differences. Results suggest abrupt transition from hay to limit-fed high-energy diets is feasible, and that limiting concentrate intake reduces SARA risk.

Effects of Supplemental Zinc on Finishing Cattle Performance and Carcass Characteristics

C. L. Van Bibber-Krueger, K. A. Miller, J. M. Gonzalez and J. S. Drouillard, Kansas State Univ., Manhattan

Three studies were conducted to evaluate effects of zinc (Zn) supplementation on feedlot performance and carcass characteristics. In Exp. 1, 40 crossbred steers (initial BW = 1434 ± 30.8 lb) were supplemented 0 or 8.33 mg Zilmax (Zil) and 60 or 300 ppm Zn (DM basis) to assess interactions between Zn and Zil. No Zn × Zil interactions were observed for final BW, ADG, DMI, or feed efficiency ($P \geq 0.42$). Supplementing steers with Zil for the final 22 days tended to increase ADG ($P = 0.10$), and tended to improve feed efficiency ($P = 0.06$), but did not affect final BW or DMI ($P \geq 0.30$). Increasing supplemental Zn from 60 to 300 ppm of diet DM did not affect feedlot performance; however, supplementing steers with 300 ppm Zn tended to reduce feed allotments days 19 thru 22 and day 25 ($P \leq 0.08$), and reduced consumption days 23 and 24 ($P = 0.03$) compared to steers supplemented 60 ppm of diet DM Zn. No interactions between Zn and Zil were observed for carcass traits ($P \geq 0.39$). Zilmax supplementation decreased USDA yield grade ($P = 0.05$) and tended to increase LM area ($P = 0.07$), but did not affect other carcass measurements ($P \geq 0.21$). Supplementing cattle 300 ppm Zn tended to decrease percentage of carcasses grading Select ($P = 0.08$) and increased the percentage of carcasses grading Choice ($P = 0.08$), but did not affect other carcass traits ($P \geq 0.37$). In Exp. 2, 156 heifers (initial BW = 1162 ± 14.58 lb) were supplemented Optaflexx at 0 or 200 mg/animal daily and 30 or 100 ppm supplemental Zn (DM basis) to determine if Zn supplementation affected animal responses to Optaflexx. Optaflexx was fed for 42 days, then was removed from the diet 1 day before harvest. There was a tendency for a Zn × Optaflexx interaction for dressing percentage ($P = 0.09$), but no other interactions were observed ($P \geq 0.20$). Heifers supplemented with Optaflexx had increased final BW, increased ADG, improved feed efficiency, and increased HCW ($P \leq 0.02$). Supplementing 100 ppm Zn tended to reduce ADG ($P = 0.07$), but did not affect other

performance or carcass measurements ($P \geq 0.12$). In Exp. 3, 480 heifers (initial BW 849 ± 28.83 lb) were supplemented 0, 30, 60, or 90 ppm Zn (DM basis) for 144 days to determine effects on feedlot performance. Increasing dietary Zn concentration tended to reduce DMI (linear effect, $P = 0.07$) resulting in a linear improvement in feed efficiency ($P = 0.03$). Final BW and ADG were not affected by dietary Zn concentration ($P \geq 0.52$). No differences were detected for HCW, dressing percentage, LM area, 12th rib fat, percentages of carcasses grading Select or Choice, or yield grade ($P = 0.53$). There was a tendency for a quadratic effect of Zn concentration on percentage of carcasses graded as USDA Prime, with percent Prime peaking at 60 ppm added Zn. Carcasses from heifers supplemented 60 ppm zinc had the greatest numerical increase ($25/carcass) in carcass value compared to the other treatments ($P = 0.32$). Overall, increased Zn supplementation minimally affects animal response to beta agonist administration, but supplementing up to 60 ppm Zn improved feed efficiency and may increase carcass value of feedlot cattle.

Yeast supplementation reduced the immune and metabolic responses to a combined viral-bacterial respiratory disease challenge in feedlot heifers *A.B. Word[1], P.R. Broadway[2], N.C. Burdick Sanchez[2], S.L. Roberts[3], J.T. Richeson[3], P.J. Defoor[4], M.D. Cravey[5], J.R. Corley[5], M.A. Ballou[1], and J.A. Carroll[2],[1]Texas Tech Univ., Lubbock, [2]USDA-ARS-LIRU, Lubbock, [3]West Texas A&M Univ., Canyon, [4]Cactus Feeders, Amarillo, [5]Phileo-Lesaffre Animal Care, Milwaukee, WI*

Two treatments were evaluated in commercial feedlot heifers to determine the effects of a yeast supplement on immune and metabolic responses to a combined viral-bacterial respiratory disease challenge. Thirty-two beef heifers (324 ± 19.2 kg BW) were selected and randomly assigned to one of two treatments and fed for 31 d: Control (CON), receiving no yeast supplement in the ration, or yeast (YEAST), control ration plus a combination live yeast (2.5 $g \cdot hd^{-1} \cdot d^{-1}$) and yeast cell wall (2.5 $g \cdot hd^{-1} \cdot d^{-1}$) supplement (Phileo-Lesaffre, Milwaukee, WI). On d -3 all cattle were challenged intra-nasally with 1×10^8 pfu BHV-1 and allowed to rest in outdoor pens for 3 d. On d 0, all cattle were challenged intra-tracheally with an average dose of 3×10^7 cfu *Mannheimia haemolytica*, fitted with an indwelling jugular catheter and indwelling vaginal temperature recording device, and were moved into individual stanchions in an enclosed barn. Whole blood samples were collected at the time of BHV-1 challenge at 1-h (serum) or 2-h (complete blood cell counts) intervals from 0 to 8 h, and at 12, 24, 36, 48, 60, and 72 h relative to *M. haemolytica* challenge. Data were analyzed using the mixed procedure of SAS specific for repeated measures with fixed effects of treatment, time, and their interaction. There was no difference in cortisol concentration or vaginal temperature between treatments ($P \geq 0.37$). Although there was no treatment difference in total white blood cell count following BHV-1 challenge ($P = 0.21$), there was a tendency ($P = 0.07$) for cattle in the CON group to have greater neutrophils than YEAST. Serum haptoglobin concentration tended ($P = 0.13$) to be decreased in the YEAST group compared to CON. Cattle in the YEAST group had a greater serum glucose concentration relative to administration of the *M. haemolytica* challenge ($P = 0.01$) and decreased concentrations of serum urea nitrogen compared to CON ($P = 0.03$). There was no difference in serum NEFA concentration between YEAST and CON ($P = 0.37$). Nasal lesion score tended to be decreased in YEAST cattle compared to CON (2.5 vs. 3.19, $P = 0.07$). In summary, feeding a combination live yeast and cell wall yeast supplement tended to reduce the inflammatory response in beef heifers. Feeding the supplement also decreased the breakdown of metabolic substrates required to provide energy for the immune response to a respiratory disease challenge.