BEEF CATTLE PRODUCTION PRACTICES: WHAT ARE THEY WORTH?

A Dissertation

by

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ABSTRACT

Multiple investigations were undertaken to evaluate the value of three facets of beef cattle production. In the first study, price and quantity effects of β-adrenergic agonists removal from beef cattle production were estimated using a stochastic equilibrium displacement model. In the long run, beef consumers, packer/processors, and feedlots face reduced prices and increased quantities. Price and quantity of feeder calves increases. Even with reduced prices for consumers, there are also reduced prices for other market sectors, making them less profitable and threatening their economic sustainability. It also increases the number of animals needed to meet demand and increases the demand on environmental resources. β-adrenergic agonists improve both environmental and economic sustainability.

In the second study, fatty acid composition and shear force analysis, along with a discrete choice experiment were conducted to evaluate consumer preferences for sirloin steaks from steers fed post-extraction algal residue (PEAR) or conventional (grain-based) feeding systems, tenderness, quality grade, origin, use of growth technologies, and price of beef. Ninety six consumers participated in a sensory tasting panel before completing a choice set survey; 127 consumers completed only the choice set survey. Sensory tasting of the products was observed to alter the preferences of consumers. Consumers completing only the survey perceived beef from PEAR-fed cattle negatively compared to beef from grain-fed cattle, with a willingness to pay (WTP) discount of -$1.17/kg. With sensory tasting the WTP for beef from PEAR-fed cattle was not discounted relative to beef from grain-fed cattle (*P* = 0.21). No tasting consumers had much higher stated WTP values for credence attributes. Factors that influence the eating experience (tenderness, quality grade) dominated as the most influential attributes on WTP among the tasting group.

In the final study, variables influencing the mortality of feedlot cattle during their last 48 days on feed (DOF) were determined. A predictive model of mortality in the feedlot for the upcoming week was also built. Ordinary least squares, Poisson, and Negative Binomial regressions were estimated. Factors identified as influencing mortality in cattle during their last 48 DOF include weight, time of year placed in the feedyard, weather, number of animals not receiving β-AAs, feeder cattle price, DOF, and previous mortality within the population, along with combinations of several of these factors.

Results from these studies suggest there is value in each practice evaluated. Ultimately, each practice can improve economic and/or environmental sustainability. Production elements must be carefully evaluated from many angles before decisions on whether to implement or remove the practices can be decided.

DEDICATION

Jeremiah 29:11

"For I know the plans I have for you…"

This doctoral work is dedicated to God. His plans are far better than my own. When I began I thought I knew the plan, but I didn't. God used this as a way to draw me closer to Him, allowing me to grow spiritually. He revealed to me a path for my education and career that was far better than one I could have ever imagined, allowing me to pursue my passions. I pray that through this work He is glorified.

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CHAPTER I

INTRODUCTION

In the United States, beef is one of the main protein sources, with 10.9 billion kilograms of it being consumed in 2014 (USDA ERS, 2015). Even with this level of consumption, consumers are becoming increasingly more curious about their food and the production practices associated with it (National Cattlemen's Beef Association {NCBA}, 2015). This lack of knowledge, however, can also create fear among consumers regarding the production practices they know nothing about. The NCBA (2015) notes that 73% of cow-calf producers believe U.S. farms and ranches provide appropriate overall care to their cattle, while only 39% of the public believe this to be true. In 2012, the incident of "pink slime," or lean finely textured beef (LFTB), in ground beef production made national headlines due to consumer fear, even though it was an established and approved production process. The controversy surrounding LFTB demonstrated that consumers' perceptions and understanding of modern food production can quickly affect markets and/or a company's business (Greene, 2012). For this reason, producers also have concerns, knowing that their business can change in a moment due to perception.

Balanced with concern of the beef product and production practices is the price of the product. Consumers seek healthful proteins as a portion of their diet, but are limited by their budget. In 2014, the retail equivalent value of the U.S. beef industry was $95 billion (USDA ERS, 2015). Relative to other meat products, though, beef is the highest priced on a per unit basis (NCBA, 2015). Producers, on the other hand, strive to produce a quality product that will generate profit for their business. Beef is a commodity, and as such, the producers in the beef industry work with a margin product. With this, producers want to use every available technology and tool that will enhance their business.

In the economy, production and prices ultimately collide in the retail market. The concerns of the producers and consumers eventually meet here and are communicated through the economics (prices) of the products. Production inefficiencies are translated to higher prices, while disapproval from consumers places downward pressure on prices. To address concerns held by both consumers and producers, both science and economics must be drawn upon. Neither the questions regarding the concerns nor the answers to them are simple. They draw on information in each discipline, just as the businesses surrounding them do.

This research was used to address concerns about production practices and the economics of beef, held by consumers and producers by drawing together the two disciplines of animal science and agricultural economics. The things that are feared, by both producers and consumers, are probably based in both some amount of fiction and reality. Only with analysis and study can we take a step closer to the truth. Combining both fields allows these concerns to be addressed more robustly and in a more powerful way than what can be achieved by each individual discipline. The objective of this research was to examine three different facets of beef cattle production by examining the value of the given practices and the implications to producers and consumers.

CHAPTER II

LITERATURE REVIEW

β-Adrenergic Agonist Removal from Beef Cattle Production

In 2013, concerns arose in the beef cattle industry about the growth enhancing technology β-adrenergic agonists (β-AAs). There are two U.S. Food and Drug Administration (FDA) approved β-AAs feed additives, ractopamine hydrochloride (RH) and zilpaterol hydrochloride (ZH). The concerns regarding animal mobility ultimately led to announcements from major packers that they would stop accepting cattle for slaughter that had been fed ZH. This led the manufacturer of the feed additive to withdraw the product from the U.S. and Canadian markets (Centner et al., 2014).

β-adrenergic agonists

Zilpaterol hydrochloride is a β-adrenergic receptor (β-AR) subtype β_2, like clenbuterol and cimaterol. Even though ZH is strikingly different in structure compared to RH, clenbuterol, and cimaterol, ZH still faces the stigma of being more potent than RH. Early research studies indicated that clenbuterol was very potent in cattle and it is not approved for use in meat animal production in the United States (Johnson et al., 2014). So even though ZH has been studied extensively, there is still opposition for it.

Aside from animal welfare concerns, there have been several studies showing that meat from cattle fed RH and ZH is less tender. Quinn et al. (2008) found minimal effects on carcass characteristics when RH is fed to heifers. Brooks et al. (2009) observed that feeding ZH increased Warner-Bratzler shear force (WBSF) of the longissimus lumboum (LL), triceps brachi (TB), and gluteus medius (GM) muscles, but with increased postmortem aging WBSF of steaks from ZH-zupplemented beef cattle could be reduced. In 2012, Rathmann et al. also found that feeding ZH to heifers tended to decrease marbling scores and increase WBSF.

Even with concerns, β-AA still offer several benefits to producers. Multiple studies have shown that feeding β-AAs increases HCW and ADG while decreasing DMI. Avendano-Reyes et al. (2006) evaluated the effects of two β-AA on finishing performance, carcass characteristics and meat quality of feedlot steers (45 crossbred Charolais and 9 Brangus). Three treatments were administered: 1) control (no β-AA added), 2) ZH (60 mg · steer^{-1} · d^{-1}), and 3) RH (300 mg · steer^{-1} · d^{-1}), with β-AAs added to the diets for the final 33 days of the experiment. Steers fed ZH and RH had 26% and 24% greater ADG versus the control steers, respectively. Steers fed RH had a lower dry matter intake (DMI; kg/d) than control steers, but DMI did not differ between ZH and control steers. ZH and RH use also influenced hot carcass weight (HCW), increasing HCW by 7% and 5%, as compared to control steers, respectively. Avendano-Reyes et al. concluded that ZH and RH inclusion improved feedlot performance of steers based on ADG and G:F. Additionally, HCW and dressing percentage were also increased by β-AA inclusion.

In 2007, Quinn et al. reported the effects of RH on live animal performance, carcass characteristics, and meat quality of finishing crossbred heifers (n = 302). Heifers were implanted with Revalor^2-H and received treatments of 200 mg · animal^{-1} · d^{-1} of RH or no RH supplement (control) 28 days prior to slaughter. Heifers receiving RH had an improved feed efficiency for the 28 day feeding period prior to slaughter. Similar measurements were obtained for the two treatments for dressing percent; HCW; marbling score; fat thickness; ribeye area; kidney, pelvic and heart fat; and United States Department of Agriculture (USDA) yield and quality grades. The authors concluded that RH added to the diets of finishing beef heifers improved gain efficiency by 8.7% during the 28 day feeding period with no effect on carcass quality or meat characteristics.

Baxa et al. (2010) investigated the effects of ZH administration in combination with a steroidal implant, Revalor-S, on steer performance and the mRNA abundance for β_1-AR; β_2-AR; calpastatin; and myosin heavy chain (MHC) types I, IIA, and IIX in 2,279 English × Continental yearling steers. A 2 × 2 factorial design was used for four treatments evaluating ZH fed for the last 30 days on feed with a 3 day withdrawal and a terminal implant of Revalor-S (RS). The treatments were as follows, 1) no RS or ZH, 2) only ZH, 3) only RS, and 4) RS and ZH (RS+ZH). The RS treatment increased ADG by 8.3%, the gain to feed ratio (G:F) by 5.7%, and increased DMI by 2.2%. Zilpaterol hydrochloride increased ADG, G:F, HCW, dressing percentage, and LM area while decreasing 12th-rib fat depth and marbling scores. With ZH, there was no effect on DMI. Cattle receiving both RS and ZH had the greatest increase in ADG (14.4%) and G:F (12.5%). According to the authors the effects of hormonal implant and β-AA appeared to be additive when compared with the individual treatments of ZH or RS.

Additionally, Stackhouse et al. (2012) and Cooprider et al. (2011) found that removing β-AA from beef cattle production would make the industry less sustainable because of increased greenhouse gas (GHG) emissions. White and Capper (2013) report that an increase in ADG or the finishing weight of animal increases sustainability through decreases in resources. So not only from an economic standpoint, but from the environment as well, β-AAs increase sustainability.

There is much evidence for and against β-AA. While consumers may have misgivings about the product they also do not know how removing this growth enhancing technology would affect their pocketbook. Alternatively, producers have realized efficiency increases in their operations with the β-AA products. Because of that, even though they may have misgivings themselves, they fear losing a technology that they believe has helped their business. To better understand what the loss of this product would mean for producers and consumers the effects of removal must be determined.

Equilibrium displacement models

Previously, equilibrium displacement models (EDMs) have been used to evaluate systems of supply and demand equations for multistage industries. Wohlgenant was the first to apply the term EDM to the system of equations and extend them to multistage industries (USDA ERS). Wohlgenant (1993) used an EDM to evaluate the distribution of gains from research and promotion in multi-stage production systems; both beef and pork industries were evaluated. The beef industry was divided into four segments (retail, wholesale, slaughter, and farm). Similarly, the pork industry was divided into three segments (in this case slaughter and farm were combined). Segmenting the industries allowed Wohlegenant to determine the gains for each sector. The farm level benefited more from research induced decreases in production costs and promotion than from research induced decreases in marketing costs. In Wohlgenant's 1989 paper he developed an empirical framework for retail-to-farm demand linkages. The modeling approach allowed estimation of the food marketing sector's supply/demand structure without direct information on retail food quantities. The model was applied to several commodities including beef, pork, and chicken.

In 1998, Davis and Espinoza pointed out that a major shortcoming of EDMs is the methodology used in conducting the sensitivity analysis. Equilibrium displacement models rely on elasticities, which can come from one of three places: 1) arbitrarily assumed, 2) borrowed from other studies, or 3) estimated by the authors. The first problem is the assumption that the structural elasticities are assumed known with certainty. To overcome this, authors present of table alternative elasticities; which often confuses readers and creates uncertainty as to the actual values. Second, providing only a few points can be misleading. Third, there is no way to determine if the final results are significantly different from zero. Lastly, the most serious concern is that elasticities can be judiciously chosen to generate "desired" results. When conducting an EDM the researcher forces the elasticity estimates and theory to be compatible, limiting the ability to validate the results based on actual observations. Widely different elasticity estimates lead to widely different model estimates. The potential range of likely outcomes highlights the need to estimate a probabilistic set of outcomes.

Brester, Marsh, and Atwood (2004) used an EDM to estimate short-run and long-run changes in equilibrium prices and quantities of meat and livestock in the beef, pork, and poultry sectors resulting from the implementation of country-of-origin labeling (COOL). In their EDM they included estimated COOL costs, accounting for interrelationships along the marketing chain in each meat sector, and allowing substitution to occur between meat products at the consumer level. They broke the beef industry into four sectors: 1) retail (consumer), 2) wholesale (processor), 3) slaughter (cattle feeding), and farm (feeder cattle). Similarly the pork and poultry markets were divided into sectors, although due to integration they had fewer sectors. For pork the sectors were: 1) retail, 2) wholesale, and 3) slaughter (hog feeding). Poultry had two sectors: retail and wholesale. All elasticity estimates were taken from the literature. Following Davis and Espinoza (1998), they conducted Monte Carlo simulations of the equilibrium displacement model by selecting prior distributions for each of the elasticities used in the EDM. The authors conclude that the poultry industry is the only unequivocal winner of the implementation of COOL. Their conclusion is based on increased COOL marketing costs in the beef and pork sectors, which increase retail beef and pork prices, and ultimately encourage consumers to substitute beef and pork products for poultry.

Schroeder and Tonsor (2011) reported the economic impacts of ZH adoption by the beef industry. They determined the overall market impacts and distribution of impacts across industry sectors using an EDM. This EDM model divided the beef industry into four sectors: 1) retail (consumer), 2) wholesale (processor/packer), 3) slaughter (cattle in feedlots), and 4) farm (feeder cattle from cow-calf producers). They also included dynamics of the pork and poultry markets to capture interactions between retail meat substitution for beef. Schroeder and Tonsor estimated a net return for cattle fed Zilmax® of \$24.24/animal for steers and \$15.69 for heifers in 2009. Net return benefits for packers slaughtering Zilmax-fed cattle were estimated to be \$32.92/animal for steers and \$29.57/animal for heifers. Schroeder and Tonsor's long-term market effects analysis revealed the ultimate beneficiaries to be the cow-calf producers and consumers as the benefit from feedlots and packers are transmitted through the rest of the market system. Cow-calf producers received higher prices for their cattle and consumers benefited from lower prices for beef at retail stores.

Thus, the question of the effects of β-AA removal is well suited to be addressed by a stochastic EDM. This application will describe the effects for producers and consumers in the livestock and meat industry of removing β-AA from beef cattle production.

Sirloin Steaks from Post-Extracted Algal Residue Fed Cattle

When algae is produced for biofuels only the lipid portion (approximately 20% of overall algae) is used (Richardson and Johnson, 2014). This leaves the remaining portion, post-extracted algal residue (PEAR), available for another use. However, because the production of algae for biofuels is currently unprofitable (Richardson et al., 2012), PEAR needs to bring in as much revenue as possible. One potential use of PEAR is in cattle feeding. Currently, there are only a few studies that have evaluated PEAR in cattle feeding.

PEAR feeding

Drewery et al. (2014) looked at PEAR as an alternative to cottonseed meal (CSM) as a protein supplement in cattle diets. Their objective was to determine the optimal level of PEAR supplementation to steers consuming straw. Post-extracted algal residue treatments were 50, 100, and 150 mg N/kg BW, with CSM at 100 mg N/kg BW. They found that straw utilization was maximized when PEAR was provided at 100 mg N/kg BW. Their observations suggested that cattle provided PEAR utilize straw in a manner similar to those supplemented CSM, indicating PEAR has potential to substitute for CSM as a protein supplement in forage based operations.

In 2014, McCann et al. evaluated the effect of PEAR supplementation on the ruminal microbiome of steers. Like Drewery et al. (2014), steers were supplemented at the 50, 100, or 150 mg N/kg BW levels or CSM at 100 mg N/kg BW. Relative abundance of Firmicutes increased with PEAR supplementation n the liquid fraction the samples. Results suggested that PEAR supplementation increased forage utilization though the increased members of Firmicutes within the liquid fraction of the microbiome.

Lastly, Morrill et al. (2015) studied the effects of PEAR on nutrient utilization and carcass characteristics in finishing steers. The effects of PEAR were compared to steers receiving glucose infused ruminally (GR) or abomasally (GA). Greater DMI was observed for PEAR than GR, but DMI for steers receiving GA was intermediate and not different from either PEAR or GR. Steers fed PEAR had greater marbling scores than

GA and GR. Subsequently, USDA Quality Grade was greater for PEAR than GA and GR. Finally, there was no difference in USDA Yield Grade or HCW between treatments.

Even though it has been shown that PEAR can be effectively fed to cattle, the unknown of consumer acceptance of the product remains. If consumers are not willing to purchase or eat meat from PEAR-fed cattle, then there will be no value in feeding it.

It is unknown how the use of PEAR in cattle diets will influence sensory characteristics of the meat. Differences in fatty acid levels in PEAR, relative to other feed ingredients, can affect the flavor profile. Morrill et al. (2015) observed greater marbling scores from steers fed PEAR. Smith and Johnson (2014) notes that any production method that increases marbling deposition also increases the concentration of oleic acid in beef. Oleic acid is associated with juiciness and the buttery flavor, in addition to being positively correlated with overall palatability. Thus, it will be important to evaluate the fatty acid profile of the beef samples.

Consumer acceptance

Throughout the literature, there are numerous studies regarding the elicitation of consumer preferences and willingness to pay (WTP) for food attributes. In 2003, Lusk et al. found choice experiments accurately predict the likely success of new products in the marketplace. This method is appropriate to apply in this research because while the product is still steak, it could be substantially different since it is derived from PEAR-fed cattle. The drawback, however, is that there is evidence in the literature that WTP values elicited from hypothetical methods are commonly overstated compared to non-hypothetical methods (List and Gallet, 2001; Murphy et al., 2005).

As Adamowicz et al. (1998) explains, choice experiments arose from conjoint analysis. Although, choice experiments differ from typical conjoint methods in that individuals are asked to choose from alternative bundles of attributes instead of ranking or rating them.

In 2003, Lusk et al. used a choice experiment to determine demand for beef from cattle given growth hormones or fed genetically modified (GM) corn. They mailed the survey to consumers in France, Germany, the United Kingdon, and the United States. Consumers made choices between ribeye steaks with varying levels of price, marbling, tenderness, and use/non-use of growth hormones and GM corn in livestock production. Across all four countries, preferences for steaks from cattle administered growth hormones were similar. The results of the WTP calculations indicated French consumers were willing to pay more for hormone free beef and that European consumers were willing to pay significantly more for beef not fed GM corn compared to U.S. consumers.

Ortega et al. (2012) used a choice experiment to assess Chinese consumer preferences for food safety verification attributes in ultra-high temperature (UHT) pasturized fluid milk. They selected five, two-level attributes for evaluation: price, shelf-life, government certification, third-party (private) certification and brand. Ortega et al. (2012) found that consumers have the highest WTP for government certification, followed by product brand, and third-party certification. Additionally, there was a negative WTP for UHT milk with a shelf-life longer than three months.

Chammoun (2012) used a choice experiment to estimate Texas consumers’ WTP for pecan attributes. Pecans were evaluated for five different attributes with either two or three levels. The online survey was distributed to 501 consumers (Texas residents). Results from the choice experiment indicated that consumers preferred large size pecans, pecans of the native variety, pecan halves, U.S. grown pecans, and specifically, Texas grown pecans. These studies from the literature demonstrate that the use of a choice experiment would be appropriate in determining consumer preferences for sirloin steak from cattle with different production methods.

Late Term Feedlot Mortality

In U.S. beef cattle production there are four predominate sectors: cow-calf, feedlot, packing/wholesale, and retail. The cow-calf and feedlot sectors are the live animal sectors. The feedlot sector is the finishing phase of beef cattle production and the final stage before slaughter. Mortality is inevitable in beef cattle production, but producers try to minimize this. Currently, the mortality rate is low (~1.5%) among feedlot cattle.

No matter how low the mortality rate is, producers will always want it to be lower, not only for animal welfare reasons, but for economic reasons as well. When producers observe morbid animals they monitor and doctor them. They do this because they are responsible for the welfare of the animal. Even if the death rate is low, if a feedlot has 1,000,000 head of cattle on feed throughout the course of a year that means 15,000 animals died. Even if cattle happened to cost a miniscule $1/animal that would translate into a loss of $15,000/yr for the feedyard, not including the expense that was put into the animal for feed, water, labor, medicine, etc. before it died. If mortality can be reduced at all, it has a major impact on the feedyard's profitability.

In 1986, Kelly and Janzen conducted a review of morbidity and mortality rates and disease occurrence in North American feedlot cattle. They point out that many descriptive epidemiological studies have reported morbidity and mortality rates in North American feedlots, but they are not well standardized and considerable variation occurs in the definition of rates. Kelly and Janzen state that when cattle enter feedlots there is a period of considerably increased disease occurrence, largely consisting of respiratory infections. In their review, the incidence of morbidity ranged from 0% to 69% with most reports between 15% and 45%. For mortality, the rate ranged from 0% to 15% with most reports between 1% and 5%. Few other epidemiological descriptions (season, day of the week, geographical, age, sex, or breed) had been objectively described in the literature they reviewed. The most common clinical and necropsy diagnoses were respiratory infections, often described as shipping fever.

In 2001, Loneragan et al. evaluated trends in feedlot mortality ratios over the January 1994 through December 1999 time period, by primary body system affected, and by type of animal. Data on feedlot cattle submitted to the National Animal Health Monitoring System (NAHMS) sentinel feedlot monitorying program through feedlot veterinary consultants was used. Month-end data submitted for the feedlots included total number of cattle that entered the feedlot, cattle inventory, and number of deaths attributable to respiratory tract, digestive tract, and other disorders for the preceding month. Relative risks of body system-specific deaths for each year, compared with 1994, were estimated using Poisson regression techniques. When averaged over time, the mortality ratio was 12.6 deaths/1,000 cattle entering the feedlots. The mortality ratio increased from 10.3 deaths/1,000 cattle in 1994 to 14.2 deaths/1,000 cattle in 1999, but this difference was not statistically significant ($P = 0.09$). Cattle entering the feedlots during 1999 had a significantly increased risk of dying of respiratory tract disorders, compared with cattle that entered during 1994. Respiratory tract disorders accounted for 57.1% of all deaths.

Cernicchiaro et al. (2012) quantified how different weather variables during corresponding lag period (considering up to 7 d before the day of disease measure) were associated with daily bovine respiratory disease (BRD) incidence during the first 45 d of the feeding period for autumn-placed feedlot cattle. Data were analyzed with a multivariable mixed-effects binomial regression model. Their results indicated that several weather factors (maximum wind speed, average wind chill temperature, and temperature change in different lag periods) were significantly ($P < 0.05$) associated with increased daily BRD incidence, but that their effects depended on several cattle demographic factors (month of arrival, BRD risk code, BW class, and cohort size). The authors believe their results demonstrate that weather conditions are significantly associated with BRD risk in populations of feedlot cattle, pointing out that estimates of effects may contribute to the development of quantitative predictive models.

As pointed out in the literature, the greatest spike in feedlot mortality is within the first few weeks of the cattle entering the feedlot. Even though the mortality decreases after the first few weeks it does not become zero. Cattle will continue to die throughout the feeding period all the way until slaughter. When cattle die right before slaughter it is more costly to the feedyard than if they had died immediately after arrival. As each day passes, the cattle accrue more costs from consuming feed and water, requiring labor to care for them, and potentially veterinary costs along with many other capital and operating expenditures. Even though it is more costly when these cattle die, there is very little literature evaluating mortality in this specific subset of cattle in the feedyard. As Cernicchiaro et al. (2012) pointed out, estimates of effects of mortality may contribute to the development of quantitative predictive models. Not only would predicting mortality be useful in improving animal welfare, but would hopefully reduce the cost from cattle dying.

Babcock et al. (2013) used a multivariable negative binomial regression model to quantify effects of cohort (lot)-level factors associated with combined mortality and culling risk in cohorts of U.S. commercial feedlot cattle. Their objective was to evaluate combined mortality and culling losses in feedlot cattle cohorts and quantify effects of commonly measured cohort-level risk factors (weight at feedlot arrival, gender, and month of feedlot arrival). Retrospective data representing 8,904,965 animals in 54,416 cohorts from 16 U.S. feedlots from 2000 to 2007 was used. Babcock et al. (2013) found mean arrival weight of the cohort, gender, and arrival month, and a three-way interaction (and corresponding two-way interactions) among arrival weight, gender, and arrival month to be significantly ($P < 0.05$) associated with the outcome. Their results illustrated the importance of utilizing multi-variable approaches when quantifying risk factors in heterogeneous feedlot populations.

In 1994, McDermott and Schukken reviewed explanatory studies in the veterinary epidemiology literature, in which clusters (herds) were sampled and individual responses were measured. Their primary objective was to describe the statistical methods used to adjust for cluster effects. Of the 67 papers in their sample, 36 (54%), used some form of adjustment for clustering. They found that including a fixed effect for herd was employed most frequently. This was done by including a dummy variable in linear models, using Mantel-Haenszel statistics, or by adjusting for mean herd production. Without using cluster effects, inferences may be made that are not actually significant. In the other 31 (46%) of the papers evaluated, changes in inference were predicted when cluster effects were correctly used.

Also in 1994, McDermott et al. outlined a variety of study design and statistical methods to account for the clustering of animal health and production outcomes. For normally distributed data they recommended using weighted least squares, post-hoc adjustment of variance estimates, and fixed or random effects models. The methods suggested for categorical responses were fixed-effect logistic regression, post-hoc adjustment to test statistics, the use of over dispersion parameters, or compound random-effect models. Lastly, with count data, fixed effect models, Poisson distribution with over dispersion, and compound Poisson distributions are suggested. Most importantly, they state that the choice of method(s) to account for clustering in studies of animal populations will depend on two main considerations: the objectives of the study and the assumptions that can be made about the nature of the correlation structure.

Most recently in 2014, Loneragan et al. quantified the association between β-AA administration and mortality in feedlot cattle and explored variables that confounded or modified that association. Their primary variable of interest was the number of animals that died in each group during the at-risk period. Similar to Babcock et al. (2013), they used a multivariable Poisson regression model. They also used a group-level term, forced into the model, to account for potential over dispersion of the data. Loneragan et al. (2014) found the cumulative risk and incidence rate of death to be 75% to 90% greater in animals administered β-AA compared to contemporaneous controls. Additionally, they observed that during the exposure period, 40%-50% of deaths among groups administered β-AA were attributed to administration of the drug. As seen in the literature, regression models are appropriate in quantifying multivariable effects on mortality in cattle. Care must be taken to assure the data is modeled correctly, however.

Predominately, studies evaluating mortality in beef cattle production at the feedlot level focus on mortality during the first several weeks after arrival into the feedyard. Additionally, a larger set of potential variables needs to be evaluated. If only a few variables are evaluated, it may be the case that a variable that is seemingly influencing mortality is instead correlated and is acting as a proxy for a different variable that is actually influencing mortality, but has been left out of the dataset. Due to the increased value of the animal near the end of the feeding period, further research is needed to determine what factors are influencing the mortality rate. This study will evaluate several potential factors and determine which are the most influential.

CHAPTER III

β-ADRENERGIC AGONIST REMOVAL: WHAT'S THE COST?

Overview

Price and quantity effects of β-adrenergic agonists (β-AA) removal from beef cattle production were estimated using a stochastic equilibrium displacement model (EDM). In this analysis, zilpaterol hydrochloride (ZH) and ractopamine hydrochloride (RH) were removed from beef production. Profitability changes from the removal of the β-AA technology for a feedlot and packer/processor were used as exogenous shocks to the EDM. An enterprise budget was used to estimate the change in profitability. Enterprise budget variables influenced by the use of β-AA were estimated with a production growth model. Cattle not consuming β-AA had an average DMI of 9.46 kg/d (6.99-13.16 kg/d range) and an average ADG of 1.62 kg/d (1.22-2.03), while in the β-AA scenario, DMI averaged 9.50 kg/d (6.93-12.29) and ADG averaged 1.78 kg/d (1.36-2.75). For the feedlot, change in profitability ranged from -$23.11 to $100.28/animal with β-AA. Initially, percentage change in quantity produced decreases in the retail (-2.68%), packer/processor (-2.68%), and feedlot (-4.26%) market levels, relative to a base of no β-AA removal. After market signals (price) are realized, quantity of feeder cattle changes. Because of the initial decrease in quantity, price of beef increases in the retail (3.77%), packer/processor (5.18%), and feedlot (11.94%) markets. Quantity and price changes in pork and poultry markets are minimal in the beginning, but increase as the market adjusts. Over six years, as the market moves towards equilibrium, beef quantities at all market levels, except feedlot, increase (0.56% retail, 1.17% packer/processor, -0.12% feedlot cattle, and 0.48% feeder cattle). Beef price decreases by 6.68% in retail, 6.32% in packer/processor, and 7.06% at feedlot. Feeder cattle price increases by 15.46%. Quantities increase in all pork market levels (4.12% retail, 11.11% wholesale, and 2.48% slaughter). Pork price decreases at the retail and wholesale levels, but increases at the feeder level (-18.61% retail, -19.00% packer/processor, and 25.69% feeder). For poultry, quantity decreases at retail (-2.94%) and price increases slightly (0.46%). Generally beef consumers, packer/processors, and feedlots face reduced prices and increased quantities. Price and quantity of feeder calves increases. Pork consumers, packer/processors, and growers face increased quantities, with decreased prices for consumers and packers and increased prices for growers. Poultry consumers see decreased quantities and increased prices.

Introduction

β-adrenergic agonists (β-AA), feed additives used to increase beef and pork production efficiency, have come under increasing scrutiny by meat companies, importing countries, and some consumers. While approved for use by the international standards body, Codex Alimentarius, United States trading partners, in 2013, banned imports of beef not certified as having been produced without β-AAs. Additionally, a domestic beef packer, stated in 2013 that they would no longer purchase cattle fed zilpaterol hydrochloride (ZH; Zilmax, Merck Animal Health, Summit, NJ), based on animal welfare concerns as they attributed the feeding of Zilmax to an increase in nonambulatory or lame cattle (Roybal, 2013). β-adrenergic agonists (ZH and ractopamine hydrochloride [RH; Optaflexx, Elanco Animal Health, Indianapolis, IN]) allow feed to be converted more efficiently generating more lean muscle mass and less fat, resulting in increased meat production (Baxa et al., 2010; Quinn et al., 2007). Additionally, the use of β-AA improves environmental sustainability by decreasing greenhouse gas (GHG) emissions, consumption of natural resources, and nitrogen and phosphorous excretion (Stackhouse et al., 2012; Cooprider et al., 2011; White and Capper, 2013). Firm level economic sustainability has been investigated by Lawrence and Ibarburu (2007), Schroeder and Tonsor (2011), White and Capper (2013), and Cooprider et al. (2011). Each have found that the use of β-AA improves economic sustainability. However, because of continued scrutiny and discrimination, β-AA may be removed from the market. The objective of this research is to examine economic sustainability, not only on a firm level, but on the United States markets, by determining price and quantity effects on livestock and meat markets due to removal of both β-AA feed additives (RH and ZH) from the U.S. beef production process. In this analysis β-AA feed additives (RH) is assumed to continue to be used in pork production.

Materials and Methods

To estimate domestic price and quantity effects, the literature was first reviewed to determine the effects of β-AA inclusion on live animal ADG and DMI, along with carcass weight and yield changes (Avendano-Reyes et al., 2006; Baxa et al., 2010; Quinn et al., 2007). This information from the literature was used to build a production growth model, based on the Nutrient Requirements of Beef Cattle (NRC) model (NRC, 2000), which estimated change in animal level production due to the removal of β-AA. Subsequently, the information from the production growth model was combined with price and quantity information to create a feedlot enterprise budget. Annual average 2012 U.S. price and quantity data from the USDA, compiled by the Livestock Marketing Information Center was employed in the enterprise budget. Additionally, changes in packer/processor costs were estimated.

Change in production and profitability of feedlots and packer/processors were used as input information, as well as the annual average 2012 U.S. price and quantity data, to the equilibrium displacement model (EDM). Price and quantity effects of β-AA removal from beef was estimated by a Monte Carlo simulation EDM at four market levels (retail, packer/processor, feedlot, and farm) for beef, pork, and poultry markets. The EDM simulation model, programmed in Microsoft Excel, used the Simetar add-in (Simetar 2011; College Station, TX), used for simulation and econometric risk analysis, to incorporate risk via Monte Carlo simulation. The processes are summarized in Figure 1.1.

The production growth model draws from the from Nutrient Requirements of Beef Cattle (NRC) model (NRC, 2000). The NRC does not currently include an adjustment factor for β-AA use in their DMI or ADG equations. Thus, a factor similar to the implant factor was created using data from the literature (Baxa et al., 2010; Quinn et al., 2007) and incorporated into the NRC equations. The β-AA adjustment factor for DMI was calculated as:

$$BA_{DMI} = 1 + \frac{\left(ZH\ \%\ \Delta\ DMI\ * ZH\ Market\ Share\ (\%)\right) + (RH\ \%\ \Delta\ DMI * \ RH\ Market\ Share\ (\%))}{(ZH\ Market\ Share\ (\%) + RH\ Market\ Share\ (\%))}$$

where:

$$ZH\ \%\ \Delta\ DMI\ = Average\ ZH\ \%\ \Delta\ DMI\ Individual\ Studies$$

and

$$ZH\ \%\ \Delta\ DMI\ Individual\ Study = \frac{ZH\ DMI - Control\ DMI}{Control\ DMI}$$

Similarly, the β-AA adjustment factor for ADG was calculated as:

$$BA_{ADG} = 1 + \frac{\left(ZH\ \%\ \Delta\ ADG\ * ZH\ Market\ Share\ (\%)\right) + (RH\ \%\ \Delta\ ADG * \ RH\ Market\ Share\ (\%))}{(ZH\ Market\ Share\ (\%) + RH\ Market\ Share\ (\%))}$$

where:

$$ZH\ \%\ \Delta\ ADG = Average\ ZH\ \%\ \Delta\ ADG\ Individual\ Studies$$

and

$$ZH\ \%\ \Delta\ ADG\ Individual\ Study = \frac{ZH\ ADG - Control\ ADG}{Control\ ADG}$$

In the scenario where β-AA were not used, the adjustment factor was equal to 1, thus having no influence on the DMI or ADG equations. To make the no β-AA scenario stochastic, the standard deviations of observations from cattle fed β-AA, as reported by Baxa et al. (2009) and Quinn et al. (2007) were used to simulate DMI and ADG values from the NRC equations as normally distributed. Cattle in both scenarios were considered to have implants. Dry matter intake and ADG were calculated using the equations in the NRC for both scenarios with the calculated adjustment factor for β-AA use. Dry matter intake for growing yearlings (cattle in feedlots) is calculated as:

$$DMI = \left(\frac{SBW^{0.75} * (0.2435NE_m - 0.0466NE_{ma}^2 - 0.1128)}{NE_{ma}}\right)$$
$$* ((BFAF) * (BI) * (ADTV) * (TEMP1) * (MUD1) * (BA_{DMI}))$$

Where:

SBW = Shrunk Body Weight (kg)

NEm = Net Energy of Maintenance (Mcal/d)

NEma = Net Energy Value of Diet for Maintenance (Mcal/kg)

BFAF = Body Fat Adjustment Factor

BI = Breed Adjustment Factor

ADTV = Feed Additive Adjustment Factor

TEMP1 = Temperature Adjustment Factor for DMI

MUD1 = Mud Adjustment Factor for DMI

BA_{DMI} = β-AA Adjustment Factor for DMI

Average Daily Gain was calculated as:

$$SWG = 13.91 * RE^{0.9116} * EQSBW^{-0.6837}$$

Where:

SWG = Shrunk Weight Gain (kg)

RE = Retained Energy (Mcal/d)

EQSBW = Equivalent Shrunk Body Weight (kg)

RE was calculated as:

$$RE = (DMI - I_m) * NE_{ga}$$

Where:

I_m = Intake for Maintenance (kg/d)

NE_{ga} = Net Energy Value of Diet for Gain (Mcal/kg)

I_m was calculated as:

$$I_m = \frac{NE_m}{(NE_{ma} * ADTV * BA_{ADG})}$$

Where:

BA_{ADG} = β-AA Adjustment Factor for ADG

The calculated DMI and ADG for each scenario was used in the feedlot enterprise budget.

Change in profitability due to the removal of β-AA must be specified at the feedlot level in the EDM. Change in profitability is derived from an enterprise budget for a typical large-scale U.S. cattle feedlot (40,000 animal capacity). Variables in a feedlot budget that would change with the removal of β-AA include days on feed (DOF), DMI, and ADG. These variables are used in the enterprise budget to determine feed costs, final weight of the animal, and other variable costs, as well as total revenues and expenses. Each of the feedlot budget variables specified above is related to the growth of the animal, which is altered by β-AA.

Two enterprise budgets were constructed, one for each scenario, to determine the effects of β-AA removal on profitability. For each scenario the cattle were assumed to start on feed at 340 kg. The DMI and ADG predictions with no β-AA adjustment were used for the entire DOF for the baseline scenario and for all but the last 30 DOF in the β-AA scenario. During the last 30 DOF the β-AA scenario used the aforementioned adjusted NRC prediction equation to calculate DMI and ADG. Average daily gain and DOF were used to calculate the final live weights of the cattle.

The 2012 U.S. average price for feeder cattle was used to calculate the purchase cost as a function of placement weight. Yardage, vet, and other variable costs were based on a feedlot enterprise budget reported by the University of Wisconsin (2011). β-adrenergic agonist cost was calculated as a weighted average of ZH and RH prices, and was only included in the β-AA scenario. Feed cost was estimated using 2012 U.S. commodity ingredient prices, DOF, and DMI approximated for each scenario in the NRC. Costs were added together on a \$/animal basis to obtain total expenses (\$/animal). Total revenues (\$/animal) and total expenses (\$/animal) were used to calculate Net Cash Income (NCI; \$/animal). The difference in profitability between the two scenarios was used in the EDM for the feedlot sector.

The change in profitability for the packer/processor is calculated using the reported processing and slaughter cost from the USDA Agricultural Marketing Service (AMS) Beef Carcass Price Equivalent Index Value report NW-LS410 (2014) and the final carcass weights of the cattle in each scenario. Slaughter and processing costs per animal are converted to a per hundredweight basis. Difference in slaughter and processing costs per hundredweight between the two scenarios is used as the change in profitability for the packer/processor in the EDM.

These changes in profitability, in addition to the one-time initial decrease in production, were used as the shocks, or input, to the EDM model. The EDM was composed of four sectors in the beef industry: 1) retail (consumer), 2) packer/processor,

3) feedlots, and 4) farm (feeder cattle from cow-calf producers). Three sectors were included for the pork industry: 1) retail (consumer), 2) processor/packer and 3) hog feeding. The poultry industry had one sector: 1) retail (consumer). Having retail sectors for beef, pork, and poultry allowed interactions between retail markets to be captured. International trade was also explicitly included in the model at the wholesale level for beef and pork. The framework was consistent with previous studies (Wohlgenant, 1989; Brester, Marsh, and Atwood, 2004; Schroeder and Tonsor, 2011). The packer/processor and feedlot/hog feeding sectors are analogous to the wholesale and slaughter market levels, respectively, found in the Gardner (1975), Wohlegenant (1989), Brester, Marsh, and Atwood (2004), and Schroeder and Tonsor (2011) studies.

Following standard EDM protocol, elasticity estimates reported in the published literature were used. Elasticities are used to estimate price and quantity changes and cannot be estimated in the same model. To estimate elasticities, prices and quantities must be given and not simultaneously estimated. Additionally, in 1998, Davis and Espinoza demonstrated the importance of examining the sensitivity of price and quantity changes relative to selected elasticity estimates. Often time's structural elasticities are assumed to be known with certainty and then utilized in models. This assumption is made because it is difficult to find complete sets of elasticity estimates for multiple meats and species at varying market levels in the same modeling exercise. Elasticity estimates primarily exist for the retail market level and are demand elasticity estimates. Very few supply elasticity estimates exist at any market level for any meat or livestock product. For demand elasticities, moving from the retail level to the farm level there are increasingly fewer elasticity estimates available to draw from.

All elasticity estimates, from the literature that were used by Schroeder and Tonsor (2011), were used as the foundation for the EDM. Additionally, the retail beef demand elasticity literature was reviewed to determine the distribution of that particular elasticity (Stanton, 1961; Tomek, 1965; Purcell and Raunikar, 1971; Huang, 1985; Menkhaus et al., 1985; Wohlgenant, 1985; Dahlgran, 1987; Lemieux and Wohlgenant, 1989; Moschini and Meilke, 1989; Huang, 1994; Brester and Schroeder, 1995; Kinnucan et al, 1997; Huang and Lin, 2000; Bryant and Davis, 2001; Hahn, 2001; Piggott et al., 2007). A GRKS[1] distribution, based on the results of this review, was used in simulation to generate the stochastic retail beef elasticity of demand. The GRKS distribution requires minimal parameters (minimum, middle, and maximum) for estimation and provides a 2.28% probability of outliers beyond the minimum and maximum parameters. Relational multipliers, based on the estimates from Schroeder and Tonsor (2011), were used to fix the relationship between the retail beef elasticity of demand and all other elasticities utilized in the model. During simulation, with each stochastic draw from the GRKS distribution of the retail beef elasticity of demand, all other elasticity estimates are subsequently calculated based on the relational multipliers and retail beef elasticity of demand draw. By using a fixed relationship (or correlation) between elasticities

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[1] The GRKS distribution assumes 50% of the observations are greater than the model value. Also, the distribution draws 2.28% of the values from above the maximum and 2.28% from below the minimum. Random values from outside the minimum and maximum values account for low frequency, rare observations, i.e., Black Swans.

(within sectors and across products) is assumed. Elasticity estimates and summary statistics are listed in the supplemental material, Tables 2.1 and 2.2.

The EDM was simulated recursively for 6 yr. Model output prices and quantities for yr 1 were used as the beginning prices in yr 2, and so on. The 6 yr EDM is simulated 500 times (iterations) using different stochastic elasticities and DMI and ADG values. Simulating the EDM for 500 iterations is sufficient for defining the distribution of the outcomes, by allowing opportunity for combinations from extremes (i.e., the best and worst cases and those in between) in the underlying distributions of input variables to be effectively represented. The resulting values for the key output variables (KOVs) from each iteration are used to define the empirical probability distributions of the KOV; e.g., prices and quantities produced at each level in each market (Richardson, Johnson, and Outlaw, 2012). The estimated probability distributions for the KOVs were used to define the 95% confidence interval about the estimated prices and quantities, and the skewness associated with prices.

Results and Discussion

Cattle not consuming β-AA had a mean predicted DMI of 9.46 kg/d (ranging from 6.99 kg/d to 13.16 kg/d) and a mean predicted ADG of 1.62 kg/d (ranging from 1.22 kg/d to 2.03 kg/d). In the β-AA scenario, predicted DMI ranged from 6.93 to 12.29 kg/d with a mean of 9.50 kg/d. These figures represent an increase in DMI of 0.33% on average. Predicted ADG in the last 30 DOF in the BAA scenario was 1.78 kg/d and ranged from 1.36 to 2.75 kg/d, a predicted increase of 9.7% above baseline. Figure 1.2

shows the probability density functions (PDF) for DMI in both scenarios. Figure 1.3 displays the ADG PDFs for both scenarios. The PDFs are a visual representation of the distributions. The ADG PDF for the β-AA scenario in Figure 1.3 is shifted to the right compared to the no β-AA scenario ADG PDF. This indicates that for all probable outcomes, β-AA will increase ADG.

The estimated DMI and ADG values were subsequently used in the enterprise budgets. Table 1.1 contains the basic animal information as well as calculated values used to calculate the total returns and expenses, and ultimately, the difference in profitability between the baseline (no β-AA) and β-AA scenarios. The values presented in Table 1.1 are the average values from the simulation. Change in profitability ranges from a decrease of $-23.11/animal to $100.28/animal (Figure 1.4) with β-AA. A cumulative distribution function (CDF; Figure 1.5) of change in profitability for β-AA presents the probabilities on the Y-axis and the $/animal change in profitability on the X-axis. By tracing the line on the CDF graph the probabilities and $/animal change in profitability at the feedlot can be linked. For example, there is an 11.3% chance that the $/animal change in profitability will result in a decrease from using β-AA. Conversely, there is an 88.7% probability that the $/animal change in profitability will be positive when using β-AA.

The reduction in cost for the packer ranges from $0.12-$1.12/45.4 kg with an average of $0.63/45.4 kg (Figure 1.6).

The increase in profitability for the feedlot and reduction in cost for the packer are expected results, at the given price levels. While on β-AA, the animals have a relatively unchanged DMI and increased ADG. So even though the animal may be on feed longer, the increase in revenues outweighs the increase in expenses. For the packer, their cost is reduced because the animal fed β-AA has a heavier HCW. Thus, it takes fewer animals to achieve the same number of total pounds as it would have with animals not fed β-AA. This reduces the fixed costs for the packer and environmental consequences. For both the feedlot and packer, β-AA are a profitable technology.

When β-AA are removed from beef cattle production there is a loss of a profitable technology. Additionally, HCW and dressing percentages decrease. These are shocks to the EDM, which disrupt the system. These shocks affect both the supply and demand at all market levels, for each meat product (beef, pork, poultry) because each market is interrelated. The ensuing results from the EDM represent the market system working back toward an equilibrium.

Initially, the removal of a profitable technology results in a higher cost of production. This reduces feedyard profit margin. If profit margins are to remain the same, then feeder cattle prices must go down (this represents a decrease in costs) and/or prices for slaughter cattle must increase (increase in revenue). Additionally, the removal of β-AA results in an immediate decrease in production (kg of beef), *ceteris paribus*, due to decreases in HCW and dressing percentage.

Fan graphs (Figures 1.7-1.14) start at the initial time point (baseline use) and continue outwards for six years. Lines on the fan graphs represent the twenty-fifth, fiftieth, and seventy-fifth percentiles and are the confidence intervals for the estimated means.

At the outset, quantity produced decreases in the retail, packer/processor, and feedlot market levels (Table 1.2). Feedlot cattle quantity differs from retail and packer/processor quantity because feedlot quantity is calculated on a live animal basis. Feeder cattle quantity remains constant because the β-AA technology are employed after this phase. It is not until after market signals (price) are realized that the quantity of feeder cattle changes. Price of beef in the retail, packer/processor, and feedlot market levels initially increases because of the decrease in beef production. Quantity and price changes in pork and poultry markets are minimal in the beginning (because they have not yet had time to respond), but both variables increase as the market has time to adjust. Thus, when the response comes in the second period it is large, but generally declines in the following periods as the markets move towards equilibrium.

Generally, the largest percentage changes in prices and quantities are within the first two years because of the markets responses and biological nature of animals. Percentage changes in livestock and meat prices and quantities are presented in Table 1.3. These results are relative to a base of no β-AA removal. More meat (animals) cannot be produced instantly. Depending on the reproductive cycle of the animal it can take from a few months (poultry) to a few years (beef) for production to respond with more (or fewer) total animals produced (Stillman, Haley, and Mathews, 2009). This is seen in the feedlot and feeder cattle quantity fan graphs (Figures 1.11 and 1.13). Feedlot cattle quantity decreases in the first three years as a result of market price influences, the loss of a production increasing technology, and the fact that heifers must be retained as replacements to grow the beef cattle herd (Figure 1.11). Because more feeder cattle cannot be immediately produced, the quantity produced is constant until the market is able to respond, but similarly heifers must be retained initially so the herd can be expanded. Even as the price and quantity percent change diminishes year over year, the confidence intervals around these estimates widen. As estimates build out in time, error compounds, thus widening the confidence intervals.

As each year passes, the markets work toward equilibrium and the movements within the markets become smaller. Overall, beef quantities at all market levels, except feedlot, increase. Retail increases by 0.56%, packer/processor by 1.17%, feedlot cattle by -0.12%, and feeder cattle by 0.48%. Price decreases by 6.68% in retail, 6.32% in packer/processor, and 7.06% at feedlot. Feeder cattle price increases by 15.46% though. In the pork market quantities increase in all three market levels (4.12% in retail, 11.11% in packer/processor, and 2.48% in feeder). Price decreases at the retail and packer/processor levels, but increases at the feeder level (-18.61% in retail, -19.00% in packer/processor, and 25.69% in feeder). For poultry quantity decreases at retail (-2.94%) and price increases slightly (0.46%). From the results, some economic welfare impacts can be inferred. The welfare impacts of β-AA removal were calculated for the initial time period. As prices increase and quantity decreases, consumer surplus decreases by $0.910 billion at the beef retail level. Pork consumer surplus decreases by $0.019 billion at the retail level and poultry consumer surplus decreases by $0.373 billion at the retail level. Collectively, this results in a decrease of $1.302 billion in consumer surplus at the retail market level. Consumer surplus decreases for all three meat markets initially because the producers have not yet been able to respond to the shock in the market. Initially, producer surplus will increase by these respective levels in each meat market. However, as the market works to expand and move towards equilibrium, producer surplus decreases and consumer surplus increases.

β-adrenergic agonists are a proven technology for increasing weight gain and decreasing feed intake in cattle. Depending on the market setting, β-AA are a profitable technology for feedlots and packing houses. However; animal welfare and consumer perception concerns resulted in ZH removal from the market in August 2013. This analysis examined the impact of the removal of all β-AA from beef cattle production. Removing β-AA from beef cattle production causes DMI to remain relatively unchanged (-0.33% on average), ADG to decrease (9.7% on average), and dressing percentage to decrease. This means that the cattle are less efficient at converting their feed, thus requiring more feed and time to reach the same weight. If time remains constant, then there is less meat produced when β-AA are not used. The implication is that the system is less sustainable because it requires more resources to produce less product. White and Capper (2013) report any production system that increases ADG or the finishing weight (FW) of an animal increases the sustainability. The increase in sustainability is achieved through decreases in feedstuff consumption, land use, water use, carbon footprint, and nitrogen and phosphorus excretion. β-adrenergic agonists are a critical part of a production system that helps make beef production more sustainable. Stackhouse-Lawson (2013) also pointed out that β-AA increase ADG, final BW, and HCW. Additionally, β-AA lower CH_4, methanol, and NH_3 emissions per kg HCW. So conversely, removing β-AA from beef cattle production would increase GHG emissions (ammonia by 13%, methane and nitrous oxide by 31%; Stackhouse et al., 2012; Cooprider et al., 2011).

In this analysis, the removal of β-AA resulted in a change in profitability for feedlots ranging from $23.11 to -$100.28 per animal, with an 88.7% chance that profitability would be decreased by not using β-AA. The removal of β-AA also increased costs for the processing sector by $0.63/45.4 kg on average. This reduction in profitability and increase in costs reduces the economic sustainability of these sectors. In 2007, Lawrence and Ibarburu estimated that β-AA reduced feedlot costs by $12-$13 per animal. Schroeder and Tonsor (2011) predicted an average net return from Zilmax® feeding of $21.08 per animal to feedlots, and a return of $31.68 per animal to the packer. White and Capper (2013) estimated an increase in income over costs of $0.24/d and $0.26/d for production systems that increased ADG or FW by 15% each, respectively, as compared to the control (average U.S. production). Cooprider, et al. (2011), estimated that the cost per kg of BW gain was increased by $0.23/kg for production systems not using feed additives or implants. Like here, Cooprider, et al. points out, increasing the cost of production reduces the economic sustainability of the enterprise. In every study, growth enhancing technologies have been shown to reduce costs or increase profitability. The removal of growth enhancing technologies will lead to a reduction in domestic production, an increase in imports, and reduced competitiveness in the world market (Capper and Hayes, 2012). β-adrenergic agonists are a technology that improve the economic sustainability of the beef cattle industry.

Due to the changes from β-AA removal, in the long run beef consumers, packer/processors, and feedlots face reduced prices and increased quantities of beef and animals, but both price and quantity of feeder calves increases (15.46% price, 0.48% quantity). The removal of β-AA creates a greater demand for feeder cattle because more animals are needed to maintain the same level of production, which drives an increase in demand for the number of head. Correspondingly, prices must increase to encourage the production of more feeder cattle. Additionally, price increases as well due to competition among the feedyards for the feeder cattle. However, the increase in price of feeder calves contributes to the reduction in profitability for feedlots. The feedlot sector experiences both increased input prices (feeder calves) and reduced prices for their final product (fed cattle). This is a threat to the sustainability of the feedlot sector and may cause some feedlots to go out of business. So while increased prices may seem positive for the farm level, it may eventually lead them to have less (or no) feedlots to sell their product (feeder calves) to. Pork consumers, packer/processors, and growers will face increased quantities, with decreased prices for consumer and packer and increased prices for growers. Poultry consumers will see decreased quantities and increased prices.

Time and again, β-AA have been shown to improve both economic and environmental sustainability. The results of this analysis further support this idea. β-adrenergic agonists are a technology that allow there to be fewer in animals in production to still obtain the same total kilograms of meat. This reduces the impact on the environment. As this analysis points out, the initial removal of β-AA reduces profitability and increases costs in multiple market sectors. In the long-run, even if there are reduced prices for consumers, there are also reduced prices for other market sectors, making them less profitable and threatening their economic sustainability. Additionally, it increases the number of animals needed to meet the demand and increases the demand on environmental resources. There is no question that β-AA improve both environmental and economic sustainability.

Lastly, this research has pointed to the need for a new set of comprehensive elasticities to be estimated. Both demand and supply elasticities, for all market levels, and all major meat products (beef, pork, and poultry) are needed. Existing elasticities are dated (some over 50+ years old) and are limited in about every area, except retail demand where there are many estimates. New elasticities would better represent the current market structures and would allow much more robust estimations to be made, not only in this case setting, but many others.

CHAPTER IV

THE INFLUENCE OF TASTE IN WILLINGNESS-TO-PAY (WTP) VALUATIONS OF SIRLOIN STEAKS FROM POST-EXTRACTION ALGAL RESIDUE (PEAR) FED CATTLE

Overview

Fatty acid composition and shear force analysis, along with a discrete choice experiment were conducted to evaluate consumer preferences for sirloin steaks from steers fed post-extraction algal residue (PEAR) or conventional (grain-based) feeding systems, tenderness, quality grade, origin, use of growth technologies, and price of beef. Ninety six consumers participated in a sensory tasting panel before completing a choice set survey; 127 consumers completed only the choice set survey without sampling products. Steaks from conventional and PEAR-fed steers had similar WBSF scores (1.89 kg and 2.01 kg, respectively; $P = 0.77$). Fatty acid composition differed ($P < 0.05$) only for palmitic (16:0) and nervonic acids (24:1); both were greater in steaks from PEAR-fed cattle (11% and 100%, respectively). Panelists in the sensory portion of the study evaluated beef samples for overall like/dislike, overall flavor like/dislike, beefy flavor like/dislike, and juiciness like/dislike. Panelist rating of overall like, overall flavor like, and beefy flavor like were not different between treatments ($P > 0.26$). Panelists rated the steaks from PEAR-fed cattle as juicier (6.70) than steaks from conventionally-fed cattle (5.94; $P < 0.01$). Sensory tasting of the products was observed to alter the preferences of consumers. Consumers who completed only the survey

perceived beef from PEAR-fed cattle negatively compared to beef from grain-fed cattle, with a willingness to pay (WTP) discount of -\$1.17/kg. However, with sensory tasting the WTP for beef from PEAR-fed cattle was not discounted relative to beef from grain-fed cattle (*P* = 0.21). The no tasting consumers had much higher stated willingness-to-pay (WTP) values for credence attributes. Factors that influence the eating experience (tenderness, quality grade) dominated as the most important and influential attributes on WTP among the tasting group. The use of no hormones and no antibiotics in production had a premium of \$2.34/kg among the no tasting group, but after tasting the premium was reduced to \$1.19/kg. If PEAR-fed beef came to market, there would be no need to differentiate it from conventionally-fed beef unless retailers wanted to market it as a differentiated product. If it were marketed as a differentiated product, retailers would need to hold promotional tastings to change consumer's preconceived notions about the product.

Introduction

Over the past 30 years algae have been evaluated as a potential source for biofuel production (Richardson et al., 2012). To produce biofuels, the lipid fraction of algae is extracted; the remainder, post-extraction algal residue (PEAR), can replace conventional sources of supplemental protein in forage-based diets of beef cattle (Drewery et al., 2014). Morrill (2015) evaluated effects of PEAR inclusion on nutrient utilization and carcass characteristics in finishing steers. The viability of PEAR as a feedstuff is dependent not only on its efficiency in animal production, but also on consumer acceptance of beef produced from cattle fed PEAR.

Credence attributes, or perceived benefits, are unobserved by consumers even after consumption. They include products that have local, health, environmental, and quality claims. Beef from PEAR-fed cattle, a byproduct, could be marketed under an environmental claim since algae is produced for use in biofuel production. This credence attribute may help to increase consumer acceptance and willingness-to-pay for the product.

Our objective was to describe consumer preferences for beef by conducting a discrete choice experiment (DCE) with consumers offered sirloin steaks from steers fed PEAR, from conventional feeding systems, and from grass-fed cattle. We hypothesized that participants who have the opportunity to taste steak samples will have different preferences than participants who do not taste the steak product. Those without a tasting opportunity will only have information about the steak product, while the tasting group has both the information and direct experience with the product. We hypothesized that consumers who have this experience will be willing to pay more for physical attributes than consumers without experience, and that consumers will be willing to pay more for beef from PEAR-fed cattle than conventional- or grass-fed cattle due to improved quality, flavor and tenderness attributes.

Materials and Methods

Consumer participant consent

Study procedures were approved by the Institutional Review Board of Texas A&M University for research involving human subjects. Prior to participation in this study, consumer participants were asked to read and sign a consent form as required by the Texas A&M University Institutional Review Board. Participation was contingent on the individual signing the consent form.

Carcass fabrication, cut selection and storage

Detailed descriptions of the cattle management history and experimental procedures through slaughter were previously reported (Morrill, 2015) for the conventional and PEAR-fed steers. Forty-eight h post-harvest, carcasses were partially fabricated, and Institutional Meat Purchase Specifications (IMPS 184) Beef Loin, Top Sirloin Butt, Boneless (NAMP, 2010; USDA, 2010) subprimals were collected from one side of each carcass from steers fed the conventional and PEAR treatments. Grass-fed top sirloin butts were obtained directly from Nolan Ryan Beef of Conroe, Texas. Top sirloin butts from each treatment were further cut into top sirloin butt steaks, center-cut, boneless (IMPS 1184B) measuring 3.175 cm in thickness. Each steak was individually labeled and vacuum packaged. Five of the innermost steaks were used for sensory, fatty acid, and Warner-Bratzler shear force (WBSF) evaluation. Of the five steaks selected from each subprimal, the four steaks nearest the anterior end were used for consumer panel and fatty acid analysis while the steak nearest the posterior end was used for WBSF evaluation. Steaks were aged for approximately 14 d before consumption.

Tenderness evaluation by shear analysis

Tenderness evaluation for steaks from conventional, PEAR, and grass-fed cattle was done in accordance with Voges et al. (2007). Electric griddles (Model 072306, National Presto Ind., Inc., Eau Claire, WI), set at 191 °C were used to cook steaks. Frozen steaks were thawed for approximately 24 h before cooking. After cooking, the steaks were cooled overnight at 4 °C before further preparation for the shear testing was done.

Fatty acid analysis

Total lipids of raw sirloin steaks were extracted by a modification of the method of Folch et al. (1957). Adaptations in methodology by Blackmon et al. (2015) were followed. Lipids were ether extracted in chloroform:methanol (2:1, v/v) and fatty acid methyl esters (FAME), including an additional saponification step. The FAME were then analyzed using gas chromatography.

Consumer sensory panel sample preparation

Conventional, PEAR, and grass-fed sirloin steaks were prepared for panel evaluation in the same manner as the steaks used for shear force analysis (Voges, et al.; 2007). After cooking, steaks were cut into 1.25 cm × 1.25 cm portions and fed to the panelists. Steaks were not cooled after cooking as they were for shear force analysis. Each panelist received three pieces of sirloin steak from conventional, PEAR, and grass-fed cattle. Sample cups were labeled, identifying the production method of each sample so panelists would have knowledge of the product's background before completing the choice set survey.

Consumer sensory panel methods

For the sensory panel, a total of 96 participants were recruited from the Bryan-College Station area of Texas. To qualify for the study, participants had to be at least 18 years of age and consume beef as a normal part of their diet. When recruited, panelists were told they would consume beef as a part of the study. Participants were scheduled for participation in one of four evaluation sessions. Evaluation sessions were held for 2 d with 2 sessions per day, targeting 24 consumers/session. Sensory panel sessions were performed in the Sensory Testing facility at Texas A&M University (College Station) in January 2015.

Before being seated, participants were given verbal instructions regarding ballots and sampling procedures. Participants were seated randomly in separate booths to prevent communication between panelists. Booths with red filtered lights were used to mask color variation among samples. After seating, the panelists were asked to answer a demographic and meat consumption survey. All panelists were provided with an attribute description sheet (Supplemental Material 1). In two of the sessions, the panelists received the attribute description sheet before product tasting, while in the other two sessions panelists received the attribute description sheet after product tasting. The attribute description sheet was given both before and after so the effect of the attribute description sheet would be balanced and could be accounted for, as this was not the focus of the research.

Panelists were provided double-distilled, deionized water and unsalted crackers. Panelists were instructed to take a bite of cracker followed by a drink of water between samples to cleanse their palates. Each consumer evaluated one steak sample for each of the three production methods (conventional, PEAR, and grass-fed). The order of steak provided to each panelist was randomized. Consumers rated each sample for overall like/dislike, overall flavor like/dislike, beefy flavor like/dislike, and juiciness like/dislike using 9-point, end-anchored hedonic or intensity scales, where 1 = extremely dislike and 9 = extremely like. Finally, panelists were asked to complete the choice set survey. The choice set survey consisted of eighteen different choice sets. Each choice set consisted of three hypothetical steaks, with different product attributes, and an opt-out "none of the products" option. Panelists were asked to select which product they would purchase, as if they were facing these choices in a supermarket. After completion of the study, all participants received a compensation fee of $30.

Retail market panel methods

For the retail market panel, a total of 127 participants were recruited at a local retail market store in the Bryan-College Station area of Texas. To qualify for the study, participants had to be at least 18 years of age and consume beef as a part of their diet.

Panelists were given the product attribute description sheet, demographic and meat consumption survey, and choice set survey to complete. These surveys were the same as the surveys given to the participants in the consumer sensory panel. The only difference between the two panels was that in the retail setting, participants did not have the chance to taste the products from conventional, PEAR, and grass-fed cattle. Additionally, participants in the retail market panel were not compensated.

Basic demographics of all 223 participants, along with those of the U.S. population, according to the American Community Survey (USCB, 2013), are found in Table 3.1.

Discrete choice experiment

A discrete choice experiment was conducted to elicit preferences for meat products. The decision to use a hypothetical choice experiment was made because beef from steers fed PEAR is a novel product, and as such, beef with these product attribute combinations are not currently available in retail markets. As mentioned previously, each choice set consisted of three hypothetical product choices (steaks), with different attributes, and one opt-out alternative labeled as "none of the products" alternative. The hypothetical choices consisted of six different attributes, with three levels each. The six different attribute categories were production method (grain-fed [conventional], grass-fed, PEAR-fed), tenderness (extremely tender, tender, not tender), USDA Quality Grade (Prime, Choice, Select), origin (imported, domestic, local), growth technology (hormones, antibiotics, no hormones or antibiotics), and price ($3/lb, $5/lb, $7/lb {$6.61/kg, $11.02/kg, or $15.43/kg}). The exact description of each attribute level is included in the product attribute description section of the supplemental material for this chapter (Appendix D). Thus, there were $3^6 = 729$ different steak combinations that could be described. It is burdensome and impractical to ask panelists to answer such a large number of product selections. Therefore, a fractional factorial D-efficient design with no priors was constructed in Ngene 1.1.2 (Ngene 2014; Sydney, Australia). The final design consisted of 18 choice sets with a D-error of 0.111. Each choice set contained three product alternatives plus an opt-out no purchase option. The inclusion of the opt-out option was chosen to more accurately resemble a real-life purchasing situation where a consumer may choose not to purchase any of the available alternatives.

For the purpose of estimation, production method, quality grade, origin, and growth technology were treated as discrete variables, while tenderness and price were treated as continuous variables. The choice set survey results were coded using effects coding. In effects coding, with L number of attributes, $L-1$ attributes are used, similar to dummy variable coding (Bech and Gyrd-Hansen, 2005). For dummy coding, 0 is used as the reference level, while in effects coding -1 is the reference level. Thus, the reference point is internalized in the parameter coefficient estimates and not represented in the intercept parameter estimate (Williams, 1994).

The methodology of Palma et al. (2014) was followed for this experiment. STATA 13.1 (StataCorp; College Station, TX) was used to estimate the mixed logit model. All product attributes were modeled in a random parameter framework. The model was estimated for all participants, and separated by participants who tasted the beef products, and participants who did not taste the beef products.

A pooling test was conducted to see if the parameter estimates differed structurally for those who tasted the product versus those who did not. The pooling test, based on the likelihood ratio was calculated as follows: $-2 * [log - likelihood\ value\ of\ all\ respondents + (log - likelihood\ value\ of\ tasting\ respondents + log - likelihood\ value\ of\ no\ tasting\ respondents)]$.

Coefficients of the product attributes from the consumer choice model were converted to mean WTP values. The standard deviations of the estimated coefficients were used to estimate a range of WTP using the delta method by Taylor's approximations series with a 95% confidence interval. These values were obtained under the *Ceteris Paribus* assumption, which means that each WTP estimate assumes that the WTP dollar amount calculated was for two products identical in all respects other than the specified attribute of comparison.

Statistical analysis

Effects of product type on WBSF and chemical composition were analyzed using PROC MIXED of SAS 9.4 (SAS Inst. Inc., Cary, NC). Pairwise t-tests among least squares means were conducted when the overall effect of product type was significant. Data obtained from the consumer panelist reports were analyzed with PROC GLM of SAS (SAS Inst. Inc.). The effects of order[2], treatment, sheet, and treatment × sheet were analyzed. Interactions that were not significant were removed from the model. When significant effects were observed, least squares means were separated using pairwise t-tests.

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[2] Order is the order the panelists received the steak sample, i.e. 1) steak from PEAR-fed animal, 2) steak from grass-fed animal, 3) steak from grain-fed animal. Sheet is whether the panelist received the sheet with attribute descriptions before or after they tasted the steak samples. Two groups received it before and two received it after.

Results and Discussion

Warner-Bratzler shear force and fatty acid analysis

Steaks from grass-fed steers had higher WBSF (3.37 kg; $P < 0.05$, SE = 0.03) than those from conventional (2.01 kg) or PEAR-fed steers (1.89 kg), which were similar ($P = 0.77$). Bowling et al. (1977) found that longissimus muscles from forage-finished cattle had higher shear force values than those from conventionally grain-finished cattle. Hedrick et al. (1983) determined that loin steaks from grass-fed steers had higher WBSF scores than cattle on silage or grain-fed diets. Others (Leander et al., 1978; Schroeder et al., 1980; Aberle et al., 1981; Medeiros et al., 1987; Berry et al., 1988) have reported that beef from grass-fed cattle had increased shear force values compared to beef from cattle fed grain-based diets. Alternatively, several studies (Harrison et al., 1978; Crouse et al., 1984; Bidner et al., 1985; Schaake et al., 1993) reported no statistical differences in WBSF values among beef from steers that were on grass versus grain diets.

Fatty acid composition of sirloin steak samples differed among finishing diet types (Table 3.2). Palmitic acid (16:0) was higher in steaks from grass- and PEAR-fed cattle than conventional ($P = 0.02$), but not different between grass and PEAR ($P = 0.86$). Palmitoleic acid (16:1) was lower in steaks from conventional and PEAR treatment groups compared to steaks from grass-fed cattle ($P < 0.04$, respectively), but were not different from each other ($P = 0.30$). Stearic acid (18:0) was increased in steaks from conventionally fed compared to grass-fed steers ($P = 0.04$), but stearic acid in steaks from PEAR-fed steers was intermediate and not different than steaks from conventionally-fed steers ($P = 0.86$) and tended to be different from steaks from grass-fed steers ($P = 0.06$). Both oleic (18:1, an Omega-9 fatty acid) and eicosadienoic acid (20:2, an Omega-6 fatty acid) were increased in steaks from PEAR-fed steers compared to steaks from grass-fed steers ($P \leq 0.05$). However, steaks from conventionally-fed cattle were not different than steaks from PEAR- or grass–fed cattle in oleic acid or eicosadienoic acid content ($P > 0.05$). Eicosapentaenoic acid (EPA; 20:5), the only Omega-3 fatty acid that differed among the three diet types, was greater in steaks from conventional- and PEAR-fed steers compared to steaks from grass-fed cattle ($P \leq 0.03$). Amount of EPA was not different between steaks from conventional and PEAR-fed steers ($P = 0.39$). Lastly, nervonic acid (24:1, an Omega-9 fatty acid) was increased in steaks from PEAR-fed cattle compared to those from conventional or grass-fed cattle ($P = 0.05$), which were not different ($P = 1.00$).

It was hypothesized that Omega-3 levels would be higher in steaks from PEAR-fed steers than conventional because the PEAR ingredient contains higher amounts of Omega-3 fatty acids than the conventional ingredients (Morrill, 2015), but the results do not support this hypothesis. Rather, Omega-3 levels were similar between the conventional (grain) or PEAR fed samples. Grass feeding reduced EPA, the only observed difference in Omega-3 composition. Dinius and Cross (1978) found no difference in fatty acid composition of beef from cattle consuming forage-based concentrate-based diets for three weeks prior to slaughter. Additionally, Schroeder et al. (1980) did not observe differences in fatty acid composition from intramuscular fat (longissimus) of cattle on forage- or grain-based diets. However, Faucitano, et al. (2008)

found that feeding high-concentrate diets increased the proportion of 14:1, 16:1, and 18:1 and decreased the concentrations of 18:0 as compared with forage feeding. Conversely, they found that forage-based diets increased the proportion of 18:3 in the *longissimus dorsi* muscle as compared with feeding concentrates. The results of Faucitano, et al. agree with previous studies (Mandell et al, 1998; French et al., 2000) comparing alfalfa silage or pasture feeding with diets containing large amounts of grain. Based on the results from this analysis, for consumers trying to increase their Omega-3 intake levels there does not appear to be any substantial advantage among these product choices; arguably, choosing other than grass-fed results in higher Omega-3 consumption.

Consumer sensory analysis

Panelists in the sensory portion of the study evaluated beef samples for overall like/dislike, overall flavor like/dislike, beefy flavor like/dislike, and juiciness like/dislike (Table 3.3). In the ratings for beefy flavor, there was a tendency ($P = 0.06$) for an interaction between treatment (grain, PEAR, or grass) and whether the panelist received the attribute descriptions before or after tasting the samples. Panelists rating of "Overall Like" was not significantly different between grain-fed and PEAR-fed treatments ($P = 0.73$); both were greater than the "Overall Like" rating for grass-fed ($P < 0.01$ in both cases). For both overall flavor and beefy flavor steaks from PEAR-fed cattle were rated as intermediate and not different from steaks from grain and grass-fed cattle ($P \geq 0.26$). Steaks from grain and grass-fed cattle were different, with grain-fed rated higher than grass-fed ($P < 0.04$). Panelists rated the juiciness of the steaks from PEAR-fed cattle the highest ($P < 0.01$) among the three samples. Panelists rated steaks from grain-fed cattle as intermediate between PEAR-fed and grass-fed ($P < 0.05$). Steaks from grass-fed cattle were the least juicy among the three. Schroeder et al. (1980) reported that panelists rated beef from grass-fed cattle as being less juicy and having lower overall acceptability. However, Crouse et al. (1984) showed no difference in panelist evaluation of juiciness among beef from grain and grass-fed cattle. Duckett et al. (2013) conducted a sensory evaluation using meat from grass and grain-fed steers; no statistical differences were observed for juiciness, WBSF scores, or tenderness. Reagan et al. (1977) reported that panelists rated beef from grain-fed cattle as having better flavor and overall satisfaction than beef from grass-fed cattle, but ratings for juiciness were not different. This is the first known study comparing steaks from PEAR-fed steers. These results suggest that if PEAR was used as a feed ingredient on a commercial scale, the resulting beef products may have no marketing advantage or disadvantage compared to beef from grain-fed cattle related to sensory attributes only, except perhaps for a small enhancement in the juiciness of the product. However, there may still be other attributes that differentiate the value of beef from PEAR fed cattle from grain-fed. Much like grass-fed, consumers may value beef from PEAR fed cattle based on perceived environmental impacts.

Discrete choice experiment

Primary shoppers dominated the respondent group (78%). Survey respondents came from an average household size of 2.49 individuals with an average income of $53,824 (Table 3.4). Food expenditures represented 12.80% of household income across all participants, 14.26% for the tasting respondents, and 11.77% for the no tasting respondents. Meat expenditures across all respondents, tasting, and no tasting respondents were 3.5%, 3.62%, and 3.39% of household income, respectively. Beef expenditures were 1.99% of income across all respondents, 2.15% for the tasting respondents, and 1.86% for the no tasting respondents.

Three different models were estimated. The first model included data from all respondents, the second only from respondents who had tasted the beef products, and the third included data only from respondents who had not tasted the beef products. Respondents who had not tasted the product represent consumers who are faced with a novel product when making purchasing decisions, in a retail setting. Their decisions are based on available information, but not experience. Once they purchase the product and consume it, their preferences are ‘updated’ with their experience with the product, and this may alter their preferences and repurchase of the products. The respondents who tasted the product prior to executing the discrete choice survey represent consumers whose experience has been ‘updated’ in this manner.

The log likelihood values for each of the 3 models were used in conducting the pooling test for structural changes. The parameter estimates of individuals who tasted the beef product differed structurally from those who did not taste the beef product ($P < 0.01$). Because the tasting and no tasting participants were structurally different, the results for the overall (or pooled) sample population are not reported.

Table 3.5 displays the mixed logit parameter estimation results. The model was estimated for each panelist. The parameter estimate for each attribute is the mean parameter estimate across all participants in the group. The standard error of the parameter estimate is shown in parentheses below the estimate. The standard deviation of the group's response is also listed in Table 3.5. The statistical significance of the standard deviations indicates the presence of preference heterogeneity for the measured beef attributes. This heterogeneity indicates that tastes and preferences towards production method, growth technologies, and price vary across respondents within a group (tasting/no tasting). If preferences are homogeneous, then tastes and preferences are the same among all respondents, or the same attributes are important to all respondents. Another way to think of this is if the standard deviation is small, or there is little variation among participants, then preferences are homogeneous and consumers have similar preferences for the specified attribute. On the other hand, if the variance is wide among participant's responses, then there is heterogeneity, or consumers have a wide variation in preferences for the attribute in question.

Preferences were heterogeneous within both respondent groups for not tender as compared to tender, quality grade prime compared to quality grade choice, and origin, imported versus domestic. Preferences are also heterogeneous for the tasting group for quality grade select versus quality grade choice, indicating that within this group, there were different preferences for each quality grade, and that some respondents may have been indifferent to quality grade. For the no tasting group, preferences are heterogeneous for tenderness, extremely tender versus tender. Notably, preferences are homogeneous (preferences do not vary across respondents within the group) for the extremely tender attribute in the tasting group and for the quality grade select attribute in the no tasting group. The local origin attribute is homogeneous across both the tasting and no tasting groups.

In practical terms, heterogeneous preferences mean that consumers are different and prefer different things. For example, some consumers may prefer beef from grass-fed cattle while others prefer beef from conventionally-fed cattle. This reality affords the opportunity for differentiated products or niche products in the market. Homogenous preferences suggest that all consumers prefer the same attribute. In this survey, all consumers expressed a preference for beef of local origin (defined in this study as cattle raised, fed, and harvested within a 644 kilometer {400 mile} radius of the retail location) as compared to beef of domestic origin. When tastes and preferences are homogenous then the same marketing strategy is likely to be effective across all consumers.

The negative sign and statistical significance of the no-product constant indicates that consumers were inclined to choose one of the products instead of choosing the no product option (Table 3.5). The willingness-to-pay (WTP) estimates shown graphically in Figures 3.1 and 3.2 for the tasting respondents and no tasting respondents, respectively. Additionally, WTP estimates for all attributes evaluated are contained in Table 4.2 the supplemental material for the chapter (Appendix D) in U.S. dollars per kilogram at the retail level.

When the consumers for the tasting group were recruited, they were told they would consume beef as a portion of the study. Knowing this up front may have influenced their decision of whether to participate or not. Thus, it is probable that consumers in the tasting group had a stronger preference for beef than consumers in the no tasting group.

Consumers who did not taste the beef product viewed beef from PEAR-fed cattle negatively compared to beef from grain-fed cattle with a price discount of -\$1.17/kg on average, Figures 3.1 and 3.2. However, in tasting the product, WTP for beef from PEAR-fed cattle was not discounted relative to beef from grain-fed cattle ($P = 0.21$). Thus, if beef from PEAR-fed cattle came to market it may not hold any potential marketing difference than beef from grain-fed cattle. Beef from grass-fed cattle generated an average price premium of \$0.90/kg without tasting. With the tasting, however, the beef from grass-fed cattle was discounted by an average of -\$0.75/kg compared to beef from grain- or PEAR-fed cattle. The distribution of the WTP estimates for beef from grass-fed cattle after tasting also passes through zero, indicating that there is a chance that WTP is zero. Overall, experience with the product reduced the WTP by \$1.65/kg (from \$0.90/kg to -\$0.75/kg) for beef from grass-fed cattle. This result supports those found by Umberger et al. (2009) where they found that the premium for steak from grass-fed cattle was \$1.41/kg before tasting, but fell to \$0.07/kg after tasting, even with full production and health information. Producers and retailers may wish to be cautious about aggressive response to stated consumer preference for products with which consumers have little experience, as the likelihood of repeat purchases may be lower than anticipated.

For tenderness, the non-tender attribute was negative and statistically significant for both tasting and no tasting groups. However, the magnitude increased in the tasting sample (-$2.12/kg for no tasting versus -$7.45/kg with tasting). Similarly, but on the positive side, extremely tender went from a $1.41/kg premium in the no tasting to $4.83/kg premium with tasting. Thus indicating that consumers may not think tenderness is very important or that there is little difference among tenderness levels, but consumers can differentiate and it affects WTP. The 2010 National Beef Tenderness Survey (Guelker et al., 2013) found that most steaks evaluated in their study from retail and foodservice were considered tender. This supports the idea that consumers may think there is little difference among tenderness since they do not generally find differences among the products they purchase. The increase in magnitude of the tasting sample results are supported by the WBSF results in which steaks from grass-fed steers had higher WBSF scores than those from grain or PEAR-fed steers. Similar to these results Lusk et al. (2001) found that consumers were willing to pay a premium of $2.71/kg for a tender versus tough steak. That value increased to $4.06/kg after the consumers completed a taste test. Fuez et al. (2004) also found that consumers are willing to pay a premium for more tender steaks, regardless of USDA quality grade.

Preference for Prime quality grade was not statistically different than zero in the no tasting group, but did generate a price premium of $1.23/kg in the tasting group. Additionally, preference for the Select quality grade was not different than zero in the no tasting group, but did generate a price discount of -$1.59/kg among the tasting group. The quality grade of the steak samples was not disclosed to the participants of the tasting group. Even so, the tasting group had different preferences for the quality grades than the no tasting group. This further highlights that the two tasting groups are different and do not have similar preferences, and may reinforce the suggestion that voluntary participants in the tasting group may have a generally higher level of experience with beef products or more firmly established preferences for specific attributes.

The results observed for the quality grade attributes reinforce those observed for the tenderness attributes. Consumers who did not taste the beef product tended to discount the importance of tenderness and quality grade, but those consumers who did taste the beef product found it to be much more important. The lack of WTP premium or discount for beef quality grade may indicate a lack of knowledge about the meaning of choice and select grade beef, but upon eating the product consumers can tell a difference. Additionally, this provides information about consumers making purchasing decisions at the grocery store without tasting the products. They can be likened to the no tasting group. However, when these people purchase a product at the store and then take them home, cook, and taste them, then they become similar to the tasting group. If there is truly a lack of knowledge among consumers about quality grade, then emphasis on quality grade as a market differentiation attribute may be ineffective. This idea is supported by the work of DeVuyst et al. (2014) where they found substantial confusion over quality grading nomenclature among consumers. They suggested a transition towards more descriptive terminology at the retail level. Thus, indications about the level of tenderness and juiciness may be more effective than listing the quality grade of the meat, even though they are intended to convey the same information.

At the time of this experiment, the retail market placed a $0.88/kg premium on Choice top sirloin steaks over Select (Livestock Marketing Information Center [LMIC], 2015). However, consumers in this project who did not taste the product (like consumers in a grocery store) did not place any value on the product being of Choice quality grade versus Select. If beef products were marketed in a manner that consumers better understood, such as guaranteed tender, then companies may be able to capture the more than $1/kg price premium indicated by the consumers who tasted the product. Quality grade may still be an efficient tool for marketing beef in the production chain, just not to the end consumer. Killinger et al., (2004), evaluated the preference of consumers for steaks that differed in marbling (high = upper 2/3 USDA Choice, low = USDA Select). Overall, they found that consumers found high-marbled steaks to be more acceptable than low-marbled steaks in flavor and overall acceptability when tenderness differences were minimized. Ultimately, however, consumers were willing to pay more for their preference, whether that was for high-marbled or low-marbled steaks. Fuez, et al., (2004), also evaluated the impact of USDA quality grade on WTP values. They found that marbling, the primary determinant of USDA beef quality grades, did not significantly impact panelists' WTP values.

Beef origin had similar directional results among both the tasting and no tasting groups with some differences in magnitude. In the current study, origin was defined as "imported," "local," or "domestically" produced beef (Product Attribute Descriptions, Appendix D). Imported beef was discounted -$1.37/kg on average by the no tasting group and by -$2.51/kg by the tasting group relative to domestic. "Local" beef had price premiums relative to domestic of $0.73/kg by the no tasting group and $1.37/kg by the tasting group. Although origin was not a major focus of this study, results were similar to other origin focused studies that found an increased WTP for domestic and local beef products. Maynard et al., (2003), determined that 52% of participants in their study expressed a WTP premium of 20% for locally produced steak over undifferentiated USDA Choice steak. Li, et al., (2015), also found that consumers are willing to pay $3.62/kg more for a local steak product. Lim, et al., (2011), reported that U.S. consumers are willing to pay a premium for strip loin steaks from the U.S. compared to Canada or Australia. Those authors noted that age and education of respondents were significant factors in the preference of origin, with older consumers more strongly preferring steak of domestic-origin, while this preference is more moderate among consumers with higher education levels. Mutondo and Henneberry (2007) found that U.S. grain-fed beef had a competitive advantage in the domestic market over imported beef from Australia, Canada, and New Zealand using the Rotterdam model. Lastly, Abidoye et al., (2011), found in their online survey a discount of -$4.43/kg of beef when it was not produced in the United States. In all of these studies there was not a comparison between experience (tasting) of the product and no experience. With a tasting experience, the results in each of these studies may have been changed.

Conversely, the USDA economic analysis of Country of Origin Labeling (COOL) reported that there was little to no evidence of a measurable increase in consumer demand for beef due to COOL implementation (USDA, 2015). So even though USDA’s regulatory impact analyses indicated substantial interest in COOL, it did not result in measureable increases in market-level consumer demand. Conclusions from the USDA (2015) report suggest that results from the current study should be interpreted cautiously; although consumers in the current study indicated an increased WTP for local or domestic products compared to imported products, these premiums may not be realized in the market. Perhaps the unrealized difference in demand was due to experience versus perception. When the USDA conducted the impact analysis there was no experience, only perception, but after implementation perception could have been changed by experience, as it was in the current study.

No hormones and no antibiotics had a premium of \$2.34/kg among the no tasting group, but after tasting, the premium was reduced to \$1.19/kg. The use of hormones as a growth technology had price discounts of -\$1.23/kg in the no tasting group, but was not statistically different than zero in the tasting treatment. Abidoye et al., (2011), using an online survey, found a WTP premium of \$1.68/kg when no growth promotants were utilized and a premium of \$7.58 for beef from grass-fed cattle as compared to beef from grain-fed cattle.

Overall, consumers tend to overstate their WTP with purely hypothetical choices related to credence attributes, and place more weight on physical attributes when they taste the product. This suggests that taste is the dominant attribute; consumers may have preferences or at least express preference for credence attributes, but taste can alter or reduce these expressed preferences. In the 2011 National Beef Quality Audit researchers evaluated the WTP across market sectors of several meat characteristics, one of these being eating satisfaction. For their study, eating satisfaction was most often described as flavor and tenderness by participants. They found that eating satisfaction was the only quality category for which Packers, Food Service buyers, and Retailers were willing to pay a premium, thus supporting the idea that physical attributes dominate. Willingness to pay may be increased for favorable physical attributes or, in other words, reduce their "dislike" to certain credence attributes in favor of "taste." Credence attributes are product characteristics that consumers are unable to evaluate or verify even after consuming the products without incurring excessively high information costs (Wirth, Love, and Palma, 2007; Lusk, 2013). Production method and growth technology are credence attributes. According to Lusk, et al., (2003) choice experiments operate on the assumption that consumers derive utility from consuming the product attributes rather than the product itself. This implies that the panelists who did not taste the beef product derived utility from stating that they would pay more for the credence attributes as compared to the panelists who did taste the products.

This work highlights some critical points about the WTP for beef attributes. Perception of WTP attributes are different once consumers taste beef that has those attributes. Consumer's pre-conceived notions of a value and what they place value on may change drastically when they consume the product. For example, cattle eating algae may generate a negative initial reaction, but when a consumer tastes the product, their pre-formed estimate of value changes. Some attributes may become more valuable, as observed for tenderness. A very tender steak is even more valued after a consumer samples one, and a tough one is discounted even more. This observation has implications for creating stability of demand for premium products that offer a tenderness guarantee.

Beef from PEAR-fed cattle did not differ from beef from grain-fed cattle in WBSF, fatty acid analysis, or the consumer sensory tasting. These results suggest that if PEAR were used as a feedstuff on a commercial scale that there would be no clear advantage in attempting to create a differentiated position for this product, which may in fact carry a disadvantage in this particular case. Consumers seem to overstate their WTP for credence attributes. After tasting products, factors that influence the eating experience still dominate as the most important and influential attributes on WTP. If producers can find a way to deliver on the credence attributes while not decreasing the eating experience of the meat then they will be able to command the highest premium of all.

The eating experience alters the preferences of consumers. The consumers who had the tasting experience were willing to pay more for beef from PEAR-fed cattle than grass-fed cattle. However, even with increased juiciness, these consumers were only willing to pay the same amount for beef from PEAR-fed cattle as what they would for beef from conventionally-fed cattle. Without the eating experience, participants were willing to pay more for beef from grass-fed cattle than conventional or PEAR-fed cattle. In evaluating the willingness to pay of consumers, the eating experience may be critical.

CHAPTER V

INFLUENCERS OF LATE DAY MORTALITY IN FEEDLOT CATTLE: A PREDICTION MODEL

Overview

Variables influencing the mortality of feedlot cattle during their last 48 days on feed (DOF) were determined. A predictive model of mortality in the feedlot for the upcoming week was also built. Daily lot level data was collected from 10 feedlots across the Texas panhandle and southwestern Kansas, representing over 285,000 lots of cattle that were on feed over the 2001-2012 time period. Ordinary least squares, Poisson, and Negative Binomial regressions were estimated. Factors identified as influencing mortality in cattle during their last 48 DOF include weight, time of year placed in the feedyard, weather, number of animals not receiving β-AAs, feeder cattle price, DOF, and previous mortality within the population, along with combinations of several of these factors. No single combination of factors was identified as the "perfect storm" causing a spike in mortality. The seven highest rated models (based on R^2 values), along with Poisson and negative binomial models, were tested for their ability to predict the weekly number of deaths. It was demonstrated that the model rated as the best fitting is not always the most appropriate for forecasting. The usefulness of this model is not only in identifying influential factors in mortality, but being able to use it in a feedyard business, to better prepare for adverse events before they begin.

Introduction

Each year, millions of cattle are placed in feedlots across the United States (LMIC 2015). In beef cattle production this is the finishing phase, or the final phase before slaughter. The death rate among this population is typically very low, around 1.5% (USDA, 2013). However, even with this low death rate, this can translate into several hundred animals per year for a feedlot. From an animal welfare standpoint, feedlot companies do not want cattle dying in their yards, in addition to the loss in revenue. This is especially true for cattle in the final days of the finishing phase because the costs accrued for the animal are even greater.

Thus, there is motivation to determine what factors influence death in feedlot cattle during their final days on feed. Some researchers and industry participants have claimed that the use of β-adrenergic agonists (β-AAs), especially in hot, dry weather, on black-hided, heavy cattle has caused an increase in deaths of feedlot cattle. Even more generally, Babcock et al. (2013) noted that literature quantifying effects of risk factors of feedlot mortality are limited.

For cattle in their last 48 days on feed, the objective was to determine what is influencing the death rate of these cattle. If the influencing factors can be determined, then perhaps they can be controlled, managed, or prepared for. Additionally, there was the question of a "perfect storm." Is there a combination of factors that causes a spike in mortality? The second objective was to predict mortality for the upcoming week. Ultimately, if the factors influencing mortality can be determined and managed, then mortality could be decreased, which would improve animal welfare and the bottom line for cattle feeding.

It is hypothesized that the factors influencing death will be temperature (hot), precipitation (lack of), wind speed, weight of the live animals when leaving the feedlot, use of β-AAs, sex of the animal, morbidity and mortality of the animals in previous periods, along with combinations of these variables.

Materials and Methods

Data was collected from 10 feedlots across the Texas panhandle and southwestern Kansas for the 2001-2012 time period. The lot level data was collected daily. Additionally, weather data was retrieved from the nearest National Oceanic and Atmospheric Administration (NOAA) weather station to each feedlot. Meteorological terminal aviation routine (METAR) weather report data was not used because it did not date back to 2001 in all locations needed. Weather records were then associated with each individual lot record. After collection, data was aggregated to the week level.

Description of dataset

Table 5.1 presents the variables collected. Variables were collected for cattle that were in their last 48 DOF. Dry matter intake (DMI) data was included, but was later removed from the dataset. Several feed ticketing issues could not be resolved so the DMI data were deemed unreliable for the analysis.

Total headcounts from each feedlot were used to weight the data when it was aggregated to a weighted average weekly value. Relative humidity and heat index were not available. Days in week were used to adjust for pens that were sent to slaughter mid-week. When aggregated to the week level, there were 627 weekly observations in the dataset. This aggregation represents over 285,000 lots of cattle that were on feed over the 2001-2012 time period.

Variable and model selection

Because one goal was to predict mortality for the upcoming week, the variables collected were used in calculations to create new variables that were used in the final model. Initially, variables were transformed into the following: percent steers/heifers in the sample population, percent of animals classified as low/high risk, number of animals on feed in the feedyard, percent of total population at each feedyard, percent of sample population not consuming a beta agonist (or percent consuming Optaflexx®/Zilmax®), percent mortality in the current week, percent mortality in previous weeks, percent mortality in previous weeks due to respiratory, digestive, musculoskeletal, or other causes, and percent morbidity in previous weeks. In the case where variables summed to one or were a linear combination of each other, i.e. percent steers and percent heifers, one of the terms had to be left out of the regression equation. Additionally, to account for seasonality and trend effects, sine, cosine, and trend variables were added.

Statistical analysis was done using SAS 9.4 (SAS Inst. Inc., Cary, NC). Multiple processes were used in this analysis, including PROC REG, PROC MIXED, and PROC GENMOD. The basic form of each of these processes was to develop a regression of the form $Y_i = f(X_1, X_2, \ldots, X_n)$, where Y_i is the dependent variable, number of deaths per week, and X_i represents all of the potential independent or explanatory variables. The

PROC REG and PROC MIXED commands are used for computing linear models. With PROC REG specifically, an ordinary least squares (OLS) regression is estimated, while PROC GENMOD can be used for estimating nonlinear regressions such as Poisson and Negative Binomial. Regardless of the linear or nonlinear form, the goal of each is to explain the relationship between the X and Y variables. The idea being that the response variable, Y varies with a set of independent variables X_i. In general, regression analysis uses the relation between two or more variables so that another can be predicted. That is one of the goals in the present analysis, to use a combination of variables to predict the weekly number of deaths.

Results and Discussion

Model development

To begin, temperature data variables were individually graphed in scatter plots against current week deaths. Because of the similar shape of all temperature graphs in relation to current week deaths it was determined that only one representative temperature estimate needed to be used in the analysis, so maximum temperature was chosen.

As an initial attempt to try and determine which variables might be important, nearly all variables were included in an OLS regression. The dependent variable, number of deaths in current week of record, was modeled as a function of trend, percent heifers, percent high risk, total number of head on feed, number of head at feedyard one, number of head at feedyard two, number of head at feedyard three, number of head at feedyard four, number of head at feedyard five, number of head at feedyard six, number of head at feedyard seven, number of head at feedyard eight, number of head at feedyard nine, number of head at feedyard ten, percent receiving Optaflexx®, percent receiving Zilmax®, in weight, year, week, previous mortality, previous mortality due to respiratory reasons, previous mortality due to digestive reasons, previous mortality due to musculoskeletal reasons, previous mortality due to other reasons, previous morbidity, precipitation, and maximum temperature.

A step-wise regression was calculated as another way to try and determine the relative importance of each potential independent variable. From the stepwise regression, it was determined that "week" was the single most explanatory variable in the mortality rate. However, it was hypothesized that week number of the year could be capturing a number of factors. Furthermore, week of the year does not help to predict anything that can be managed in a feedlot setting. So week number of the year warranted further investigation to try and determine what week represented.

Following the step-wise regression, each potential independent variable was regressed on the number of deaths per week. This was done to further evaluate the relationship between each individual independent variable and the dependent variable, number of deaths in a week. Scatter plots were also built with the number of deaths and each of the potential independent variables. Based on the seasonal pattern of the placement day/week deaths scatter plot, the determination was made to transform the placement dates into placement day of the year on the Gregorian calendar. For example, January 1st is the first day of the year and December 31st is the 365th day of the year.

When the scatter plots were built, their shapes were evaluated to see if they were linear, log, exponential, quadratic, or of any other form. Scatter plots were also graphed for the independent variables versus the weekly mortality rate and compared to the scatter plots made with the number of week deaths. The graph shapes were identical. Therefore, we decided it did not matter which variable was used and continued working with the number of week deaths variable. Most graphs turned out linear and did not have specific shapes or trends. Of the group, the most promising were: placement day of the year, days on feed, in weight, maximum temperature, and week (Figures 5.1-5.5).

The in weight graph (Figure 5.1) showed a slight upward trend. As the weighted average for in weight of the population increased so did the number of deaths in a week. This is contrary to the typical line of thought in the cattle industry. The belief is that the heavier cattle are upon arrival, the fewer health problems they will have in the feedyard. This may be true to some extent. Perhaps the heavier cattle are less sick upon arrival and the immediate weeks following, but has the industry compared the health status of heavier and lighter cattle during their last 48 DOF?

Figure 5.2 graphs the deaths per week according to the number of DOF. The relatively small downward trend indicates that as the weighted average number of DOF for the population increases that the number of deaths per week decreases. In this case, there is an element of survivability. Cattle who are weaker will probably die earlier, but as the end of the time period is reached, the group that is left are probably hardier. Still, the idea that deaths could decrease as cattle are on feed longer is still curious.

Maximum temperature and deaths per week are displayed in Figure 5.3. Again, the downward trend goes against the grain in regards to sentiments that are commonly heard in the cattle industry. It is often heard that mortality problems arise from feeding black-hided cattle for more days, consequently getting them bigger (combined with the use of β–AAs) in the summer heat. While it is unknown if that statement is true, Figure 5.3 shows a smattering of increased deaths at cooler temperatures.

If the same line of anecdotal thought was followed, then it would be expected that deaths for cattle in their last 48 DOF would be increased during the summertime. However, Figure 5.4 shows an increase in deaths during the early and late weeks of the year, or wintertime. It is logical that deaths could also be increased in the wintertime. The first notion is that these wintertime deaths would be related to weather events.

Figure 5.5 is a graph relating deaths per week to the weighted average placement date of the cattle population. The graph shows there is a strong seasonality element to deaths and it is not constant over the course of the year. Evaluating this graph raised curiosity about what time of year, on average, the cattle were coming in that had higher death rates and if there was anything associated with this group of cattle that would increase deaths.

Placement dates were transformed to placement day of the year. After transforming placement date to day of the year, placement day of the year was graphed with deaths per week in a scatter plot (Figure 5.6). This graph revealed the clearest shape seen yet in all the scatter plots. A clear curve, peaking around the 220th-270th days of the year (August 8th – September 27th) was evident. It is suspected that the cattle dying in the wintertime have an average placement date of August 8th through September 27th. Observing this graph raised curiosity further as to what was influencing the death rate of these cattle during their last 48 DOF.

Over the August 8th through September 27th time range there was a smattering of increased deaths above the curve. When thinking about cattle deaths, we also wanted to know if there was some sort of “perfect storm” or combination of factors that increased deaths. The 30 or so points above the curve presented themselves as potential candidates for the suspected combination of factors. These points were separated for further investigation. Henceforth, they will be referred to as the high death rate dataset.

In combination with the high death rate dataset, a new set of variables were created. Instead of expressing mortality as a percent due to a reason, mortality due to a reason was expressed as a percent of mortalities, i.e. respiratory deaths as a percent of total deaths.

Summary statistics were computed for each variable in the high death rate and overall datasets. The variables were compared to check for possible influence on death rates. Similar to the scatter plots, weather was identified. The average of maximum temperature declined from 51 °F in the overall dataset to 37 °F in the high death rate dataset. Again indicating that deaths predominately occur in the wintertime. Precipitation increased from 0.32” to 0.4” in the high death rate dataset while snowfall increased from 0.08” to 0.3”. Respiratory mortalities as a percent of mortalities increased from 69% to 75% while mortalities due to other causes remained about the same. The average number of DOF decreased from 91 in the overall dataset to 86 in the high death rate dataset.

After completing this preliminary analysis to determine which variables might play a role in the deaths of cattle in their last 48 DOF, several OLS models were estimated. These iterative model estimations with their variables are listed in Table 5.2. The following second order and interaction terms were created and included in the OLS analysis: maximum temperature squared, precipitation squared, precipitation × maximum temperature, snowfall × maximum temperature, in weight × placement day of year, in weight × placement day of year × DOF, placement day of year × DOF, and in weight × placement day of year × DOF × maximum temperature × precipitation.

Five linear regression models were initially estimated. Adjusted R squared values were in the 54%-57% range. The five model iterations estimated the number of deaths per week using different combinations of the variables: trend, previous week percent morbidity, maximum temperature, precipitation, snowfall, sine, cosine, respiratory mortality as a percent of total mortality, in weight, DOF, placement day of the year, maximum temperature squared, precipitation squared, precipitation × temperature, snowfall × temperature, in weight × placement day of the year, DOF × placement day of the year, in weight × placement day of the year × DOF, and in weight × placement day of the year × DOF × maximum temperature × precipitation. Variables that were not significant at the $P < 0.05$ level were noted. These variables were tried in multiple iterative models, but if they continued to not be significant they were eventually dropped as potential variables. Of the five model iterations estimated, there was one model iteration in which all the variables were significant. This model iteration included the variables: trend, previous week percent morbidity, maximum temperature, precipitation, sine, cosine, respiratory mortality as a percent of total mortality, in weight, DOF, placement day of the year, maximum temperature squared, and in weight × placement day of the year × DOF × maximum temperature × precipitation (model iteration 4, Table 5.2).

After the first five regressions trend, sine, and cosine were removed from the estimations even though they had been significant (Table 5.2). This was done in an attempt to remove the time series element from the model and make it more of a biological model. Trend, sine, and cosine are not variables that can be managed for and do not explain how a business can improve. On average, this decreased the adjusted R squared value by about 11%. The weekly average corn, feeder cattle, and fat cattle prices were added to the model iterations (separately, in combination, and all together). The price variables were added to capture some of the seasonal effect that the trend, sine, and cosine variables may have been capturing. In addition, these prices do influence feedyard companies' decisions about how long to keep cattle on feed or when to buy cattle for the feedyard. Of these price variables and combinations thereof, using only the feeder price was determined to be the best according to adjusted R squared values and significance values for the individual variables.

Before more model iterations were estimated the decision was made to only include two-way interaction terms, with the exception of a couple of three-way interaction terms that made logical sense. More interaction terms were also created.

These variables are: maximum temperature × number of animals not receiving a β-AA, maximum temperature × percent of animals not receiving a β-AA, precipitation × maximum temperature × previous week morbidity percentage, placement day of year squared, in weight squared, percent of animals not receiving a β-AA × out weight, percent of animals not receiving a β-AA × DOF, placement day of the year × feeder cattle price, DOF × feeder cattle price, and in weight × feeder cattle price. These variables, along with those used previously made up the bank of variables used for further analysis.

The previous model iteration that was selected as best out of the group of five was used as the starting point for further analysis. The first model iteration that had all significant variables included: in weight, precipitation, maximum temperature, DOF, placement day of the year, price of feeder cattle, maximum temperature squared, precipitation × maximum temperature, and in weight × placement day of the year × DOF (model iteration 6). The next model iteration estimated used the same variables, but added maximum temperature × percent of animals not on a β-AA (model iteration 7, Table 5.2). All variables in this iterative model estimation were significant as well. Because the maximum temperature × percent of animals not on a β-AA variable was not significant in the subsequent models it was removed (model iteration 8). The three way interaction term of in weight × placement day of the year × DOF was also split into two way interaction terms and tested for significance (model iteration 8). The DOF portion was found not to be significant and was also dropped from further model estimations. Next, the squared terms of placement day of the year, in weight, and interactions involving percent of cattle not receiving a β-AA were evaluated. The two squared terms were found to be significant as well as the interaction terms involving out weight and DOF when combined with the previous set of significant variables (model iteration 9). Feeder cattle price was found not to be significant in some estimations, but significant in others so interaction terms with feeder cattle price were created and included in iterative model estimations. Additionally, model iterations with the variables percent of animals receiving a β-AA and number of animals receiving a β-AA were estimated to test if using one variable other over the other made any difference (model iterations 10-17). Of the model iterations estimated there were four model iterations that had all significant variables. Variables common to these four model iterations are: in weight, precipitation, maximum temperature, placement day of the year, maximum temperature squared, precipitation × temperature, in weight × placement day of the year, placement day of the year squared, and in weight squared. The first of these four model iterations also included the variables: feeder cattle price × DOF, feeder cattle price × in weight, percent of animals not receiving a β-AA × out weight, and percent of animals not receiving a β-AA × DOF (model iteration 12). The second included: feeder cattle price × DOF, feeder cattle price × in weight, percent of animals not receiving a β-AA, and percent of animals not receiving a β-AA × DOF (model iteration 14). In addition to the variables common across all four model iterations, the third iterative model included the variables: feeder cattle price × DOF, feeder cattle price × in weight, number of animals not receiving a β-AA × out weight, and number of animals not receiving a β-AA × DOF (model iteration 16). The fourth model iteration included the additional variables: feeder cattle price, number of animals not receiving a β-AA × out weight, and number of animals not receiving a β-AA × DOF (model iteration 17).

Of all the model iterations estimated there were several variables that were consistently significant across the different models. These variables are: in weight, precipitation, maximum temperature, placement day of the year, feeder cattle price, maximum temperature squared, precipitation × maximum temperature, in weight × placement day of the year, placement day of the year squared, in weight squared, percent of animals not receiving a β-AA × DOF, percent of animals not receiving a β-AA × out weight, number of animals not receiving a β-AA × DOF, number of animals not receiving a β-AA × out weight, feeder cattle price × DOF, and feeder cattle price × in weight. Using these variables, two models were moved forward with. Model 1 used all variables except for: percent of animals not receiving a β-AA × DOF and percent of animals not receiving a β-AA × out weight (model iteration 18, Table 5.2). Model 2 used all variables except: feeder cattle price, number of animals not receiving a β-AA × DOF, and number of animals not receiving a β-AA × out weight (model iteration 19, Table 5.2). The variables previous week percent morbidity, previous week percent mortality, and respiratory mortality as a percent of total mortality were not statistically significant in a few of the model iterations. It was hypothesized that this variable should be an indication of the number of deaths per week so they were included again in further models.

Since the variables percent of animals not receiving a β-AA and number of animals not receiving a β-AA had both been found to be significant in different model iterations the decision was made to estimate model iterations including these variables along with the DOF and out weight, which had been significant in some model iterations (model iterations 20-35, Table 5.2). Each of these variables were included in the model iterations individually and then in combination with one another, except for percent and number of animals not receiving a β-AA. Also, since not all interaction terms had been estimated in a model that included the interaction terms as individual variables this was done as well. Out of these estimated models there were two new models (model iterations 26 and 35) that included the tested variables and had all significant terms. Both models included the variables: in weight, precipitation, maximum temperature, placement day of the year, maximum temperature squared, precipitation × temperature, in weight × placement day of the year, placement day of the year squared, in weight squared, feeder cattle price × DOF, feeder cattle price × in weight, and out weight. The first of these two models (Model 3 [model iteration 26]) also included the variables percent of cattle not receiving a β-AA × DOF, percent of cattle not receiving a β-AA × out weight, and percent of cattle not receiving a β-AA. The second model (Model 4 [model iteration 35]) included these same variables, but in their numeric form instead of as a percentage.

Not having a measure of mortality or morbidity included in the model did not make logical sense so these types of variables were included in Model 3 (model iterations 36-42). The variables previous week percent mortality, previous week percent morbidity, and respiratory mortality as a percent of total mortalities were tried individually and in combination with one another. Of these estimations, only one model iteration returned all significant variables (model iteration 37). It was the model that included previous week percent mortality in combination with: in weight, precipitation, maximum temperature, placement day of the year, maximum temperature squared, precipitation × temperature, in weight × placement day of the year, placement day of the year squared, in weight squared, percent of cattle not receiving a β-AA × DOF, percent of cattle not receiving a β-AA × out weight, feeder cattle price × DOF, feeder cattle price × in weight, percent of cattle not receiving a β-AA, and out weight (Model 5 [model iteration 37], Table 5.2).

After thinking further about mortality in a feedyard it was decided that a squared term should be added for previous week percent mortality. Looking at a graph of mortalities per week over time there will be peaks and valleys. So mortality does not continue to increase indefinitely, but at some point reaches a high and then turns downward. For this reason, the squared term was included. When the squared previous week mortality percentage was included it was significant along with all of the other variables in the model (Model 6 [model iteration 43], Table 5.2).

Long and Freese (2006), state that applying a linear regression model to count outcomes can result in inefficient, inconsistent, and biased estimates and even though there are situations in which the linear regression models provide reasonable results, it is much safer to use models specifically designed for count outcomes. For this reason, Poisson and negative binomial regression models were estimated. Previously, Loneragan et al. (2001) used Poisson regression to model the number of deaths in a feedlot. Because Model 6 was rated as the best fitting model, the variables from Model

6 were used in estimating the Poisson and negative binomial regression models. In the Poisson model estimation all of the same variables were returned as significant. However, in the negative binomial model (Negative Binomial 1) one variable, percent of animals not receiving β-AA × DOF, was not significant. So it was dropped from the model and the negative binomial model was re-estimated (Negative Binomial 2). In the re-estimation all variables were statistically significant. The parameter estimates for these models are presented in Table 5.3.

Lastly, because the time and energy to capture all of the variables included in the model can be expensive to a corporation the five most important variables to the model were found. To do this, a stepwise linear regression was done. A stepwise regression looks at all the potential explanatory variables and finds the single variable that contributes the most to the R^2 value of the model. In an iterative process, SAS then finds the variable that contributes the second most to increasing the R^2 of the model. The five variables that contributed the most to the R^2 of the linear regression model (Model 7, Table 5.3) are maximum temperature, in weight squared, percent of animals not receiving a β-AA × DOF, feeder cattle price × DOF, and feeder cattle price × in weight. In total, six variables would need to be tracked to create these five variables.

Model evaluation

The F values and adjusted R-squared values for models 1-7 are also listed in Table 5.3 with the parameter estimates. All models are significant at the 0.01% level. Thus, the adjusted R-squared value is used to determine which model is the best fitting. Model 6 has the highest adjusted R-squared value and a statistically significant F value, indicating that it is the best fitting model. The reduced model, Model 7, is the poorest fitting. However, it requires the least effort to track the data required. The log likelihood values for the Poisson and negative binomial models are listed in Table 5.4. The goal is to maximize the log likelihood value, thus, the negative binomial 1 model is the best fitting of the 3. Although there is only a slight difference between it and the negative binomial 2 model. It is not surprising that the negative binomial models are better fits than the Poisson model. A limitation of the Poisson model is that it requires the mean and the variance to be equal, which is often not the case. In the estimation of the negative binomial models an alpha, or dispersion, value is estimated. The alpha parameter reflects unobserved heterogeneity among observations (Long and Freese, 2006). If the Wald 95% confidence limits for this dispersion coefficient do not include zero then the data is over-dispersed, suggesting that a negative binomial model will be a better fit than a Poisson model (UCLA, 2015).

The signs on the parameter coefficients are constant across all models presented in Tables 5.3 & 5.4. Keep in mind that the variables in the models are all weighted averages of the population for the weekly observation. This changes how one thinks about the interpretation of the parameter coefficients a little. The coefficient for the variable in weight is positive and goes against intuition a bit. Typically light weight, younger cattle are associated with higher death rates. However, this is in regards to cattle that die during their last 48 DOF. This parameter indicates that mortalities increase as the in weight of the population increases, which may be a product of the cattle available during a certain point in the year. Combining this with the in weight squared parameter, which has a negative coefficient, more insight is gained. The negative coefficient indicates that at extreme levels (high or low), mortality will decrease. It is in the middle that mortalities increase. Perhaps this is because more attention gets paid to the light weight cattle that arrive because managers assume that they will have increased morbidity and mortality within that group, so the bigger cattle are not paid as much attention. Previously, Babcock et al. (2013) noted that animal weight at feedlot arrival, gender, arrival month, weather, and commingling of cattle have been found to be associated with feedlot mortality risk. This supports the idea that weight at arrival is an influencing factor, but these previous studies evaluated all cattle at the feedlot, not just those during their last 48 DOF. Additionally, this study had a far greater number of variables to work with compared to the five variables (gender, arrival weight, date of arrival, days on feed and lot size) that were available to Babcock et al. (2013).

The parameter coefficient for out weight is also positive, indicating that mortalities increase with increased out weights. This relationship fits the bias currently held by most of the industry in that the cattle are essentially “too big” to support themselves and are dying because their cardiac and respiratory systems can’t keep up. However, if these cattle are, on average, heavier when they arrive in the feedyard it would make sense that they are also heavier when they leave the feedyard as well. So, it may be an artifact of the demographics of the cattle population, not necessarily any physiological reasons.

Placement day of the year has a positive coefficient, indicating that mortalities increase as the average placement date moves later in the year. This corresponds with Figure 5.6 showing that generally deaths increased as the average placement date moved later in the year. Combining this information with the squared term of placement day of the year gives a clearer picture. The estimated parameter coefficient for the squared term is negative. This indicates that there is a peak during the year for mortalities, with respect to the placement day of the year, also corresponding with Figure 5.6. However, as Ribble et al. (1995) notes, arrival weight and month are two common risk factors that are often difficult to separate due to the seasonal marketing patterns of feeder cattle in North America. Similarly, Loneragan et al. (2001) states that the animals in their evaluation did not necessarily enter the feedlot during the same month or even the same year that they died, making estimation of the ratio of deaths to cattle entering the feedlot difficult. This same issue is true of the present analysis. Because the present analysis is evaluated on a weekly aggregation, instead of on a lot level, it is unknown whether the cattle placed in the later portion of the year are dying that same winter or when specifically they are dying. Being able to tie that information together would help to paint a better picture as to why placement day of the year matters in predicting late day mortality.

Only one model used the variable feeder price and the estimated parameter coefficient was negative. The feeder price variable was included as a proxy for some of the cyclical nature of mortalities throughout the year, instead of using the sine and cosine variables. There is no biological reason why mortality would decrease as feeder prices increase. In production economic theory, as the price of the marginal value product increases it becomes economically rational to invest more in it. Cattle are the marginal value product, so as feeder cattle price increases, it is rational that feedyards would invest in better health care to reduce mortality.

Both the percent and number of animals not receiving a β-AA have positive coefficients. So, as a greater number of the population receives a β-AA there are fewer mortalities. As mentioned previously, this too is counterintuitive to the current frame of thinking in the industry. Loneragan et al. (2014) found that β-AAs increased the cumulative risk and incidence rate of death by 75-90%. Lyles and Calvo-Lorenzo (2014) state that scientific progress on β-AA-related welfare concerns includes variable findings on behavioral and physiological effects seen across several species and β–AA drugs, with little evidence of welfare implications on β–AA and feedlot cattle in the literature (in reference to the 2014 Loneragan et al. study). Thus, it is not surprising that the results of this study differ from Loneragan et al. (2014). While both evaluate β–AA, their datasets of cattle are different, and thus, are under the influence of different management practices, which could in turn alter the effect that β–AA have on cattle, i.e. no influence of β–AA on cattle when fed for the lower end of the approved feeding range. Additionally, in several of the cases worked with by Loneragan et al. (2014) there were significantly fewer covariates available to evaluate than what was available in this study. Some of the cattle in their study were also fed β-AA to the upper end of the approved feeding range, which could have greatly influenced the increase in mortality. Because of the lack of explanatory variables in the Loneragan et al. (2014) study β-AA may have been identified as the cause for an increased death rate when it was not truly the sole reason for the increase. From the present study, it appears that there is some protective effect from death when cattle are consuming a β-AA. It may also be the case that β-AA are more regulated, and thus there are tighter management controls in place when they are being fed, in turn helping to reduce mortality. Again, the exact meaning is hard to decipher as this dataset is aggregated across the entire population on feed for a given week.

For previous week percent mortality, as it increases, mortalities in the population also increase. This conclusion makes logical sense, that as the number of mortalities for last week increases then mortalities for the current week would be higher as well. Additionally, the variable previous week percent mortality squared has a negative sign on its coefficient estimate. Together, these two variables can be likened to the flu (or other sicknesses) in humans. Each winter, the number of flu cases starts at a few, but then grows over the course of the winter, with more people coming down with it each week. There is a tipping point somewhere though. When it is reached, the number of flu cases will decline until the spring when it reaches some minimum level. It is similar in cattle, if there is some sort of outbreak or seasonal factor causing death, it will spread through the population killing many animals. When the tipping point is reached the number of mortalities will subside. Mortalities do not continue increasing indefinitely. Also observed in Figure 5.4 was that mortalities are the greatest during the winter. Loneragan et al. (2001) found that the monthly mortality ratio for animals that died of respiratory tract disorders was highest during November through January. They go on to state that although the time from feedlot arrival to death was not reported in the present study, they expected that most animals that died of respiratory tract disease did so early in the feeding period. While digestive deaths may be more prevalent later in the feeding period, death due to respiratory causes was still the most common reason.

Maximum temperature has a negative coefficient, while maximum temperature squared has a positive parameter coefficient. The negative parameter estimate for maximum temperature indicates that as temperature increases that mortalities decrease. However, the squared parameter puts a limit on death from temperature. When temperature reaches either very high or low points, mortalities will increase in this range. In other words, at temperature extremes, very cold or brutally hot, mortalities will increase. As precipitation increase mortalities will increase as well. Precipitation is a weather event that can cause stress in the animals, in turn influencing the number of mortalities. With the interaction term maximum temperature × precipitation, there are two halves to the tale. The parameter coefficient is negative. So, when temperatures are cold and there is precipitation along with it, then mortalities will be increased. Alternatively, when temperatures are higher and there is precipitation, the precipitation can act as a cooling effect and reduce the number of mortalities. The variables humidity and heat index were not available back to 2001 in the weather data or they would have been tested for inclusion in the models. It is hypothesized that these two variables may also play important roles in predicting the mortality of cattle in a feedlot.

Lyles and Calvo-Lorenzo (2014), note that records in several regions of the United Sates show that severe heat waves or winter weather have resulted in substantial cattle mortality. They specifically reference two anecdotal cases (one blizzard and one heat wave with high humidity) in which thousands of head of cattle were lost. Additionally, Cernicchiaro et al. (2012) found that several weather factors (e.g., wind speed, wind chill temperature, and temperature) are associated with increased daily incidence of respiratory disease. While, only the above weather variables were found to be significant it was observed that mortalities due to respiratory problems was the greatest cause of mortality. No weather factors were found to have an interaction with any of the other variables. Cernicchiaro et al. (2012) does point out that mitigating weather impacts through management approaches is challenging without defining the specific weather conditions and cattle populations that result in an increased risk. It is possible though that no interaction term was identified with weather and a specific population of cattle since their analysis was already studying a subset of the population. Their study indicated that several weather factors (maximum wind speed, mean wind chill temperature, and temperature change) were siginificantly associated with increased daily bovine respiratory disease complex (BRD) incidence, but their effects depended on several cattle demographic factors (month of arrival, BRD risk code, BW class, and lot size). Even though the Cernicchiaro et al. (2012) study looked at cattle during their first 45 DOF in the autumn season, there is still plausible reason to believe that similar factors would affect all cattle on feed. Loneragan et al. (2014) found the most consistent modifier of the biological association between β-AA administration and mortality was month of year. They go on to state that month of year is a proxy for other variables with the most probable being thermal heat index. While thermal heat index was not able to be included here, it is evident that several other weather variables play a significant role in explaining the mortality of cattle during their last 48 DOF.

The interaction term in weight × placement day of the year has a positive coefficient. As both in weight of the population increases and as the cattle are placed later in the year, mortalities increase. This corresponds with reasons identified for each of these variables separately. The speculation can be made that these cattle are not monitored as closely because they are assumed to not have as many problems as lighter cattle coming in at the same time late in the year. However, it is difficult to truly interpret this variable without taking a closer look at the lot level data. This interaction has been discussed anecdotally in the literature, but has not been quantified for multiple cattle types and production settings (Babcock et al.; 2013). The present analysis quantifies that variable exactly.

Both percent and number of head of animals not receiving a β-AA × DOF have a positive parameter coefficient. As cattle have spent more time on feed and the percent or number of head of animals not receiving a β-AA increases, mortalities increase. When cattle are receiving a β-AA they are more closely managed and their end date is determined. However, when cattle are not receiving a β-AA they can continue to be on feed for an unspecified amount of time, depending on the market conditions and when the feedyard decides to sell them. This may be a reason why mortalities increase as the combination of these two variables increase together.

Similarly, the interaction terms percent and number of head of animals not receiving a β-AA × out weight, have the same sign on their parameter coefficient, negative. So as both of these variables increase mortalities decrease. Each of these variables individually had a positive parameter coefficient indicating that as each of the variables increased then mortalities would increase as well. In combination with this interaction term, it is suggested that there is an upper limit to those cases and they will not continue on an upward trajectory for all points.

For feeder cattle price × DOF the estimated parameter coefficient is negative. Generally, as the price of feeder cattle increases feedyards will leave their cattle on feed longer. In theory, cattle in the feedyard become worth more as price increases and thus, when one dies more money is lost. This may cause feedyards to alter their management strategies and keep a closer watch on all of the animals so the number of mortalities does not increase. Meanwhile, the parameter coefficient for the feeder cattle price × in weight interaction term is positive. This also supports the idea stated above. Price can increase for a multitude of reasons, but when it does the in weight of cattle generally increases with it. Much of this has to do with the seasonality of the available supply of feeder cattle. In the fall, when the majority of calves are getting weaned and sent to the feedyards, prices are depressed because of the glut of supply. These fall weaned calves arrive at the feedyards at a lighter weight than those that are held over the winter and placed in a backgrounding lot or on wheat pasture. The supply of stocker cattle held over the winter to gain weight is smaller relative to the supply of weaning calves that enter the feedlot in the fall. Thus, when the stocker cattle arrive at the feedyards in the spring they have an increased in weight and are coming in at a time when the price of feeder cattle is seasonally higher. Why this combination of factors increases mortality is not clear. Again, it would be extremely useful to evaluate the lot level data to try and better understand these relationships amongst the variables.

Model forecasting

The intention of estimating a model for late day mortality in feedlot cattle was to be able to use it as a predictive tool in a feedlot. To test which of the models would forecast the best three in-sample analyses were done. The first sample used the information from the 36 observations with the highest number of deaths in a week. The second sample used the information from the 36 observations with the lowest number of deaths in a week. The third sample used the entire dataset. The observations for each independent variable were used in conjunction with the estimated model parameters to predict the number of mortalities in those given weeks.

Three measures of fit were used to evaluate the fit of the forecasting models. They are the mean absolute percentage error (MAPE), mean absolute deviation (MAD) and mean squared deviation (MSD). In each case, lower values indicate a better fit. Mayer and Butler (1993) believe that due to the complexities of models and data types, there is no set combination of validation techniques which is applicable across all modeling situations and that in most cases, a number of validation measures are necessary to appreciate "the whole picture." They also state that for deviance measures, mean absolute error (or MAD) or root mean square error are recommended as more stable statistics than MAPE. Additionally, Makridakis and Hibon (1995) found that the mean square error (or MSD) is the most appropriate measure for selecting an appropriate forecasting model. The measures of fit values for each model are presented in Table 5.5.

In each sample group the ranking of the models are generally similar. For the in-sample group with the highest number of deaths the Poisson model is estimated to be the best forecasting model. Of the linear regression models, Model 5 is the best predicting, while the reduced model (Model 7) is among the lowest ranked. For the in-sample group with the lowest number of deaths the negative binomial 2 model is estimated to be the best forecasting model, with model 6 being rated as the best linear regression model in two out of the three measurements. The reduced model, Model 7, is rated as the poorest performing of the forecast model. When the whole dataset is used, the negative binomial model 1 is ranked as the best forecasting model by two of the three measures and model 6 is the best of the linear regression model. Also, as might be expected, model 7 ranks as the poorest predicting model.

There is no best model for the entire dataset and two subsets. Different models predict each of these cases better. Thus, the case could be made that in these different times, the different forecast models should be used. To use three different models, there must be triggers to indicate when to switch from using one forecast model to another. The easiest triggers to use are the means of each variable, with the means being different between the entire dataset and the high/low death datasets.

To test if the means of the groups were different, the t-test procedure for comparing group means was used in SAS. Both the high and low death datasets were compared to the entire dataset. The results specified whether the means of the two groups were different, along with providing 95% confidence limits of the variable means for each group. Triggers were selected based on a combination of factors. Trigger variables must have different means between the entire dataset and the high/low death dataset, the 95% confidence limits of the high/low death dataset variable mean must not overlap with the 95% confidence limits of the variable mean of the entire dataset, and the variable must be used in the best prediction model for the entire dataset.

The variables meeting this criteria for switching to the high death models are: maximum temperature, placement day of the year, maximum temperature squared, percent of animals not receiving a β-AA × DOF, feeder price × in weight, and previous week percent mortality squared. The variables meeting this criteria for switching to the low death models are: in weight, in weight × in date, percent of animals not receiving a β-AA, out weight, in weight squared, percent of animals not receiving a β-AA × out weight, percent of animals not receiving a β-AA × DOF, and feeder price × in weight. The 95% confidence limits of the trigger variables were used to select the trigger values for those variables. The trigger values for switching to the high death models are listed in Table 5.6, while the trigger values for switching to the low death models are listed in Table 5.7.

Once all the trigger values were selected they were tested on the entire dataset to see which weekly observations they would trigger as weeks to switch to the high or low death data models. These results were then compared to test if they triggered any of the observations that comprised the high and low death datasets. Both the high and low death datasets contain 36 observations. Of these, eight were correctly triggered for needing to switch to the high death models. There were twelve instances where the triggers indicated that the high death models needed to be used when they did not, and twenty-eight occurrences of needing to use the high death model, but the triggers not indicating so. For the low deaths, nine were correctly triggered for needing to switch to the low death models. There were fifteen instances where the triggers indicated that the low death models needed to be used when they did not, and twenty-seven occurrences of needing to use the low death model, but the triggers did not indicate so. As is evidenced here, there is error in selecting for the triggers and their values.

To decide whether these triggers should be used at all the cost of the error (over or underestimating) must be calculated. For example, the trigger could indicate switching to the high death model, but the feedyard does not and then underestimates mortality. Because mortality was not expected to be as high, the feedyard under prepares for the week, and subsequently loses more animals. The feedyard must decide if that is more costly than switching models and over-preparing. This situation would be in reverse if thinking about switching to the low death models. Thus, the decision of whether to switch to more specific models or just use the model that fits the entire dataset the best is ultimately up to the feedyard.

Conclusion

Several factors were identified as influencing mortality in cattle during their last 48 DOF. They include weight, time of year placed in the feedyard, weather, number of animals not receiving β-AAs, feeder cattle price, DOF, and previous mortality within the population, along with combinations of several of these factors. While no single combination of factors was identified as the “perfect storm” several of these individually identified factors are presumably part of it.

Some of the influential factors cannot be controlled, such as weather, and others can only be partially controlled or managed for, like mortality. Other influential factors raised even more question as to how they relate to mortality. For example, in weight and DOF, based on the observations in this analysis. Further understanding and investigation is required to learn how management factors may need to be changed so the number of mortalities can be decreased.

The fitted prediction models were tested for forecasting ability. It was demonstrated that the model rated as the best fitting is not always the most appropriate for forecasting. The usefulness of this model is not only in identifying influential factors in mortality, but being able to use it in a feedyard business, to better prepare for adverse events before they begin.

Lastly, as always, this model is a function of the data that was used to build it. Having this dataset aggregated in a weekly fashion allowed the forecast model to be built, but it also limited some of the associations of variables. This research answered a stated set of objectives, but also raised more questions in which the individual lot level data would be needed, similar to Babcock et al. (2013). As the agricultural industry moves into the era of “big data,” perhaps better relationships will be found, even though we may not be to explain them all, and some of these questions may be answered.

CHAPTER VI

SUMMARY AND CONCLUSIONS

In this research, three different facets of beef cattle production were evaluated for their value to producers and consumers. This was done by combining the animal science and agricultural economics disciplines, which allowed more robust and powerful analyses to be completed.

The first project not only evaluated the price and quantity effects of β-AA removal from beef cattle production, but its impact on the economic sustainability of the firms and consumers in the market. In the long-run, beef consumers, packers/processors, and feedlots face reduced prices and increased quantities of beef and animals, but both price and quantity of feeder calves increases (15.46% price, 0.48% quantity). This increase in price contributes to a reduction in feedlot profitability. Additionally, the feedlot faces reduced prices for their final product. This is a threat to the sustainability of the feedlot sector and may cause some feedlots to go out of business. So while increased prices may seem positive for the farm level, it may eventually lead them to have less (or no) feedlots to sell their product (feeder calves) to. These results support the belief that β-AA improve both economic and environmental sustainability.

The objective of the second project was to describe consumer preferences for sirloin steaks from steers fed PEAR, from conventional feeding systems, and from grass-fed cattle, as well as other product attributes (tenderness, USDA Quality Grade, origin, growth technology, and price). Fatty acid and shear force analyses were also conducted.

Two groups of consumers participated; a group that only had information about the steak product (no tasting group) and a group that had both the information and an experience with the product (tasting group). Steaks from conventional and PEAR-fed steers had similar WBSF scores (1.89 kg and 2.01 kg, respectively $P = 0.77$). Both were different and less than the WBSF score of grass-fed beef (3.37 kg; $P < 0.05$). Fatty acid composition differed ($P < 0.05$) only for palmitic (16:0) and nervonic acids (24:1); both were greater in steaks from PEAR-fed cattle (11% and 100%, respectively). Sensory tasting of the products was observed to alter the preferences of consumers. Consumers who completed only the survey perceived beef from PEAR-fed cattle negatively compared to beef from grain-fed cattle, with a willingness to pay (WTP) discount of -$1.17/kg. However, with sensory tasting the WTP for beef from PEAR-fed cattle was not discounted relative to beef from grain-fed cattle ($P = 0.21$). The no tasting consumers had much higher stated willingness-to-pay (WTP) values for credence attributes. Factors that influence the eating experience (tenderness, quality grade) dominated as the most important and influential attributes on WTP among the tasting group. If PEAR-fed beef came to market, there would be no need to differentiate it from conventionally-fed beef unless retailers wanted to market it as a differentiated product. If it were marketed as a differentiated product, retailers would need to hold promotional tastings to change consumer's preconceived notions about the product. Having an additional outlet for the PEAR can improve the economic sustainability of the algae companies, as well as beef producers if they are able to extract more value for their PEAR-fed beef product.

Factors influencing the death rate of cattle in their last 48 DOF were identified in the final project. Additionally, a model was built to predict mortality in the upcoming week. Factors identified as influencing mortality in cattle during their last 48 DOF include weight, time of year placed in the feedyard, weather, number of animals not receiving β-AAs, feeder cattle price, DOF, and previous mortality within the population, along with combinations of several of these factors. No single combination of factors was identified as the "perfect storm" causing a spike in mortality. The seven highest rated models (based on R^2 values), along with Poisson and negative binomial models, were tested for their ability to predict the weekly number of deaths. It was demonstrated that the model rated as the best fitting is not always the most appropriate for forecasting. The usefulness of this model is not only in identifying influential factors in mortality, but being able to use it in a feedyard business, to better prepare for adverse events before they begin. The feedyard implementing the predictive mortality model must ultimately decide which model (or combination of) to use; balancing it with the costs of implementation and upkeep compared to the value of reduced animal deaths. Reducing deaths improves animal welfare and reduces revenue loss, which helps to improve economic sustainability.

Results from these studies suggest there is value in each practice evaluated. Ultimately, each practice can improve economic and/or environmental sustainability. Production elements must be carefully evaluated from many angles before decisions on whether to implement or remove the practices can be decided.

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APPENDIX A

CHAPTER III FIGURES AND TABLES

Tables

Table 1.1. Animal information and enterprise budget for baseline and β-adrenergic agonist scenarios.

Animal Information	**Baseline Scenario**	**β-Adrenergic Agonists Scenario**
Initial Body Weight, kg	340.00	340.00
Final Body Weight, kg	567.00	606.00
Day β-Adrenergic Agonists Started		131.00
No β-Adrenergic Agonists ADG, kg	1.62	1.62
Weight at Start of β-Adrenergic Agonists, kg		553.00
β-Adrenergic Agonists ADG, kg		1.78
Total DOF	141.00	161.00
No β-Adrenergic Agonists DMI, kg/d	9.46	9.46
β-Adrenergic Agonists DMI, kg/d[1]		9.50
Yardage Expense, $/d	0.49	0.49
Feed Cost, $/kg	0.08	0.08
Total Weight Gain in Feedyard, kg	227.00	266.00
Dressing Percentage, %	62.00	63.00
Final Carcass Weight, kg	351.00	381.00
2012 Average Grid Price, $/45.4 kg	192.00	192.00
Returns, $/animal		
Total Returns	1,486.00	1,613.00
β-Adrenergic Agonists Scenario Increase in Revenue Over Baseline		127.00
Expenses, $/animal		
Purchasing Expense	1,115.00	1,115.00

Table 1.1. Continued

Animal Information	**Baseline Scenario**	**β-Adrenergic Agonists Scenario**
β-Adrenergic Agonists Expense		15.42
Feed Expense	543.00	620.00
Yardage Expense	69.00	79.00
Vet Expense	3.00	3.00
Other Variable Expenses	50.00	50.00
Total Expenses	1,781.00	1,883.00
β-Adrenergic Agonists Scenario Increase in Expense Over Baseline		-102.00
Net Cash Income, $/animal	-295.00	-269.00
β-Adrenergic Agonists Scenario Increase in Profitability Over Baseline, $/animal		25.21

[1] Two DMI values are listed in the β–adrenergic agonist scenario because the animals are not fed β–adrenergic agonists until their last thirty days on feed.

Table 1.2. Equilibrium displacement model average price and quantity estimates for individual market sectors by year.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Retail Beef Quantity, billion kg	8.26	8.04	8.31	8.02	8.31	7.93	8.31
Packer Beef Quantity, billion kg	11.75	11.44	11.67	11.45	11.72	11.47	11.89
Fed Cattle Quantity, billion kg	19.20	18.38	18.78	18.39	18.88	18.43	19.17
Fed Cattle Quantity, 1,000 animals	32,425.40	31,042.96	30,805.90	31,064.90	31,893.21	31,125.16	32,387.93
Feeder Cattle Quantity, billion kg	10.14	10.14	10.14	10.05	10.19	10.06	10.18
Feeder Cattle Quantity, 1,000 animals	29,792.73	29,792.73	29,792.73	29,544.95	29,955.30	29562.44	29,936.36
Retail Beef Price, $/45.4 kg	502.30	521.25	491.51	520.04	484.82	522.40	468.77
Packer Beef Price, $/45.4 kg	190.70	200.58	191.61	199.70	187.85	197.02	178.64
Fed Cattle Price, $/45.4 kg	122.86	137.53	127.61	136.18	123.11	132.31	114.18
Feeder Cattle Price, $/45.4 kg	148.45	148.45	166.28	145.87	167.95	141.67	171.40
Retail Pork Quantity, billion kg	8.23	8.23	9.06	8.20	8.58	8.12	8.57
Packer Pork Quantity, billion kg	10.56	10.56	11.66	11.22	11.64	11.30	11.73
Fed Hog Quantity, billion kg	10.57	10.57	10.89	10.53	10.86	10.59	10.84
Retail Pork Price, $/45.4 kg	346.70	346.80	291.30	346.76	296.50	337.49	282.17
Packer Pork Price, $/45.4 kg	84.63	84.63	71.86	76.68	70.95	74.94	68.55
Fed Hog Price, $/45.4 kg	83.66	83.66	106.36	93.54	105.05	93.30	105.15
Retail Poultry Quantity, billion kg	14.29	14.42	13.92	14.44	13.98	14.48	13.87
Retail Poultry Price, $/45.4 kg	189.30	188.88	190.59	188.93	190.17	188.72	190.17

Table 1.3. Equilibrium displacement model average percent changes in price and quantity for individual market sectors by year.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Retail Beef Quantity, % change	-2.68	3.37	-3.41	3.60	-4.47	4.98
Packer Beef Quantity, % change	-2.68	2.01	-1.88	2.41	-2.12	3.66
Fed Cattle Quantity, % change	-4.26	2.15	-2.13	2.65	-2.34	4.03
Feeder Cattle Quantity, % change	0.00	0.00	-0.82	1.37	-1.28	1.23
Retail Beef Price, % change	3.77	-5.59	5.94	-6.56	8.53	-9.71
Packer Beef Price, % change	5.18	-4.43	4.26	-5.80	5.14	-9.42
Fed Cattle Price, % change	11.94	-7.07	6.80	-9.25	8.20	-14.15
Feeder Cattle Price, % change	0.00	12.01	-11.56	15.72	-13.94	26.18
Retail Pork Quantity, % change	0.00	0.01	-0.02	0.03	-0.05	0.07
Packer Pork Quantity, % change	0.00	0.01	-0.01	0.02	-0.03	0.05
Fed Hog Quantity, % change	0.00	0.00	0.00	0.01	-0.01	0.01
Retail Pork Price, % change	0.03	-0.06	0.08	-0.11	0.18	-0.19
Packer Pork Price, % change	0.00	-0.01	0.02	-0.04	0.05	-0.10
Fed Hog Price, % change	0.00	0.03	-0.04	0.08	-0.09	0.21
Retail Poultry Quantity, % change	0.86	-1.24	1.30	-1.43	1.84	-2.11
Retail Poultry Price, % change	-0.22	0.28	-0.28	0.30	-0.37	0.41

[1] Percent changes are relative to a base of no β–AA removal.

Figures

Figure 1.1. Flow diagram[3] of information and models used in estimating the price and quantity effects of β-adrenergic agonists removal in livestock.

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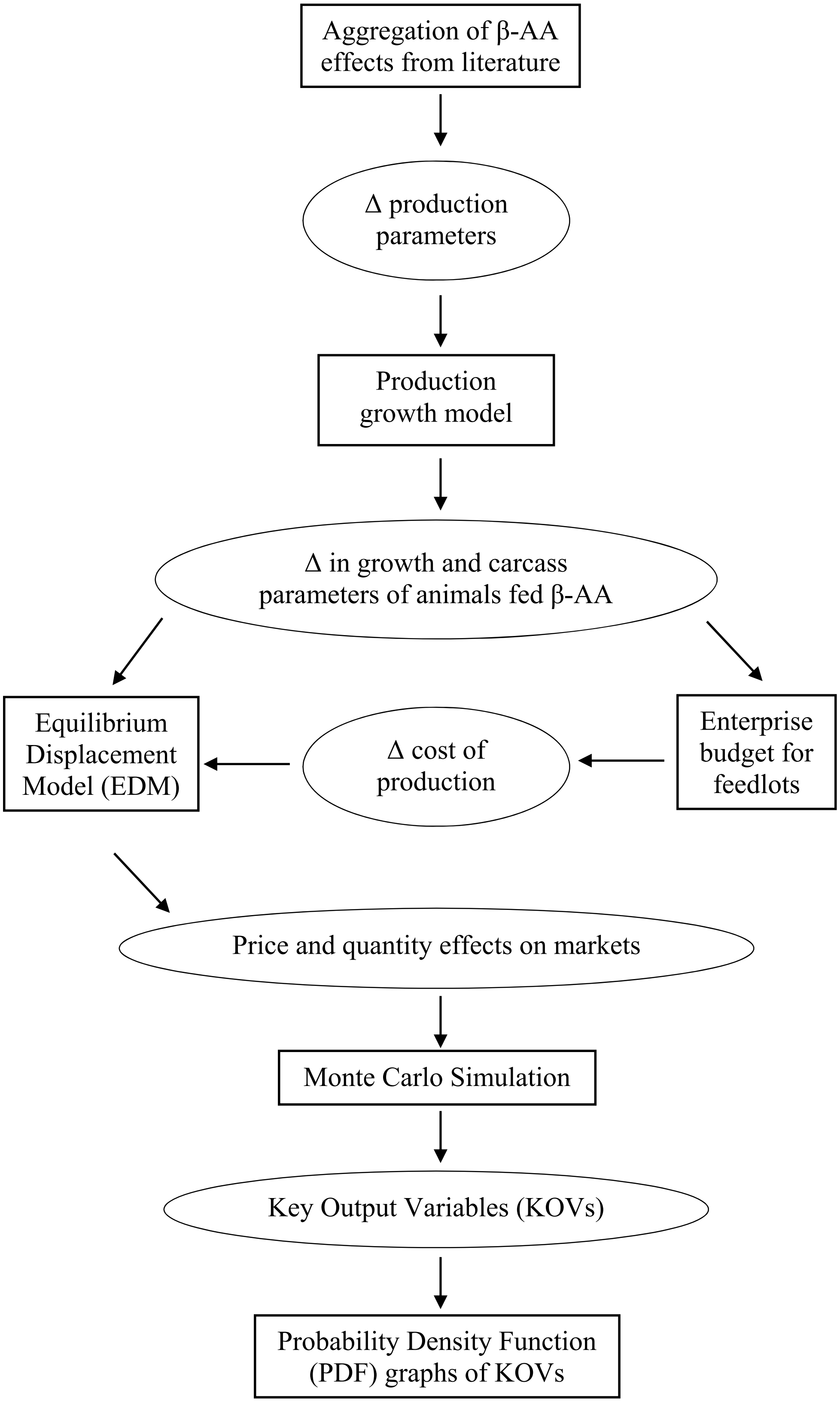
[3] Squares indicate model process elements and ovals indicate information flows.


Aggregation of β-AA effects from literature
Δ production parameters
Production growth model
Δ in growth and carcass parameters of animals fed β-AA
Equilibrium Displacement Model (EDM)
Δ cost of production
Enterprise budget for feedlots
Price and quantity effects on markets
Monte Carlo Simulation
Key Output Variables (KOVs)
Probability Density Function (PDF) graphs of KOVs

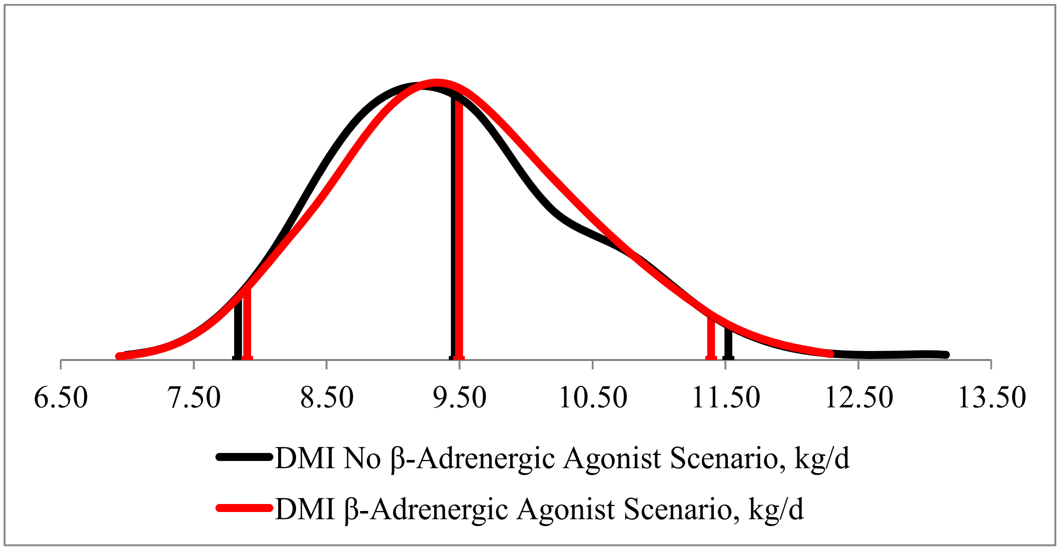


Figure 1.2. Probability density function of DMI for β-adrenergic agonists and no β-adrenergic agonists scenario.

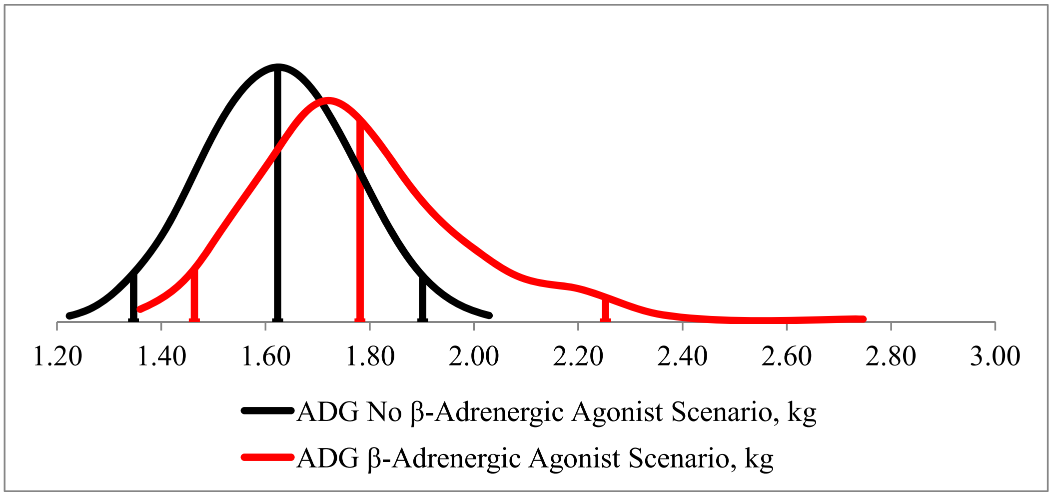


Figure 1.3. Probability density function of ADG (Kg) for no β-adrenergic agonists and β-adrenergic agonists scenarios.

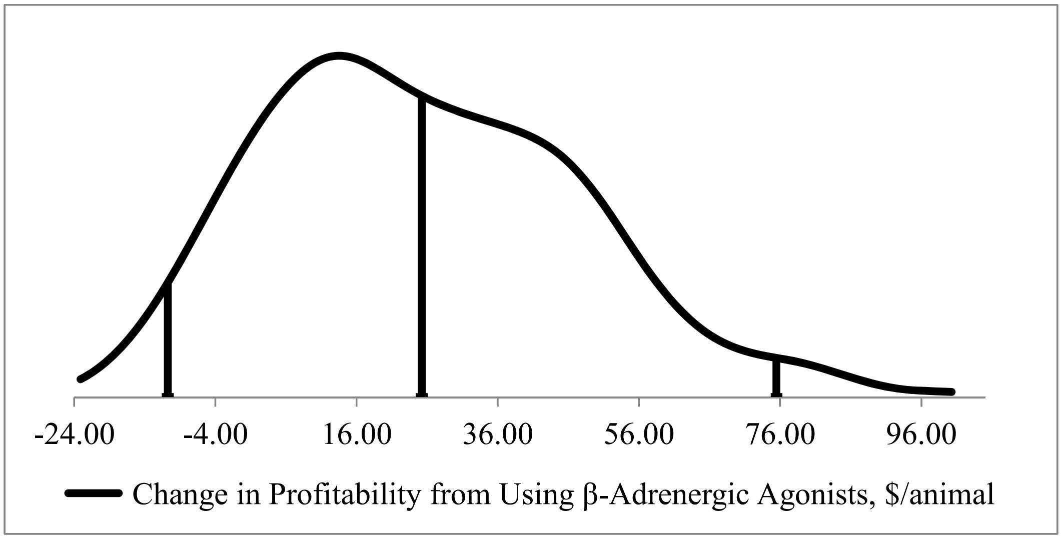


Figure 1.4. Probability density function of feedlot change in profitability due to β-adrenergic agonist inclusion.

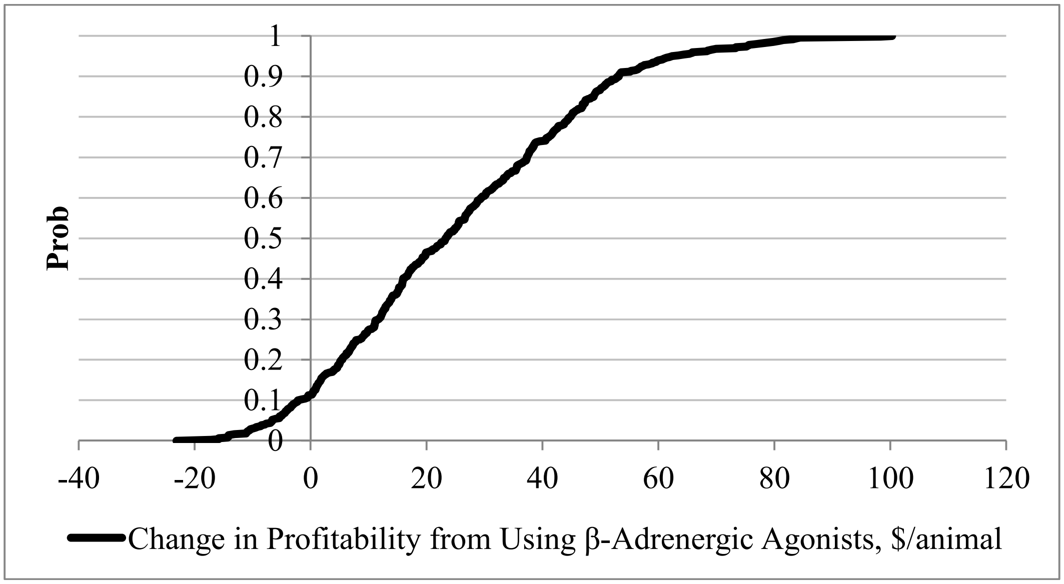


Figure 1.5. Cumulative distribution function of feedlot change in profitability due to β-adrenergic agonist inclusion.

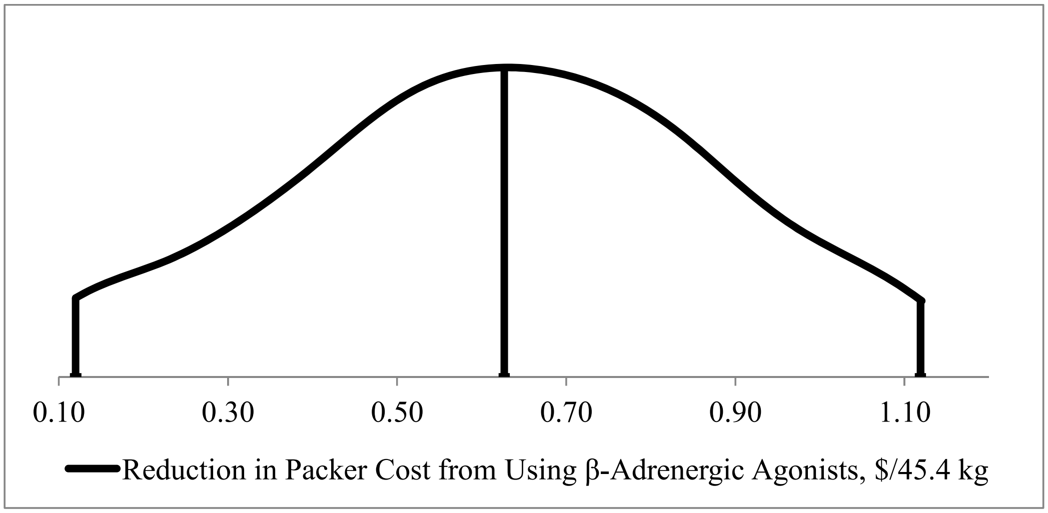


Figure 1.6. Probability density function for reduction in cost for packer due to β-adrenergic agonist inclusion.

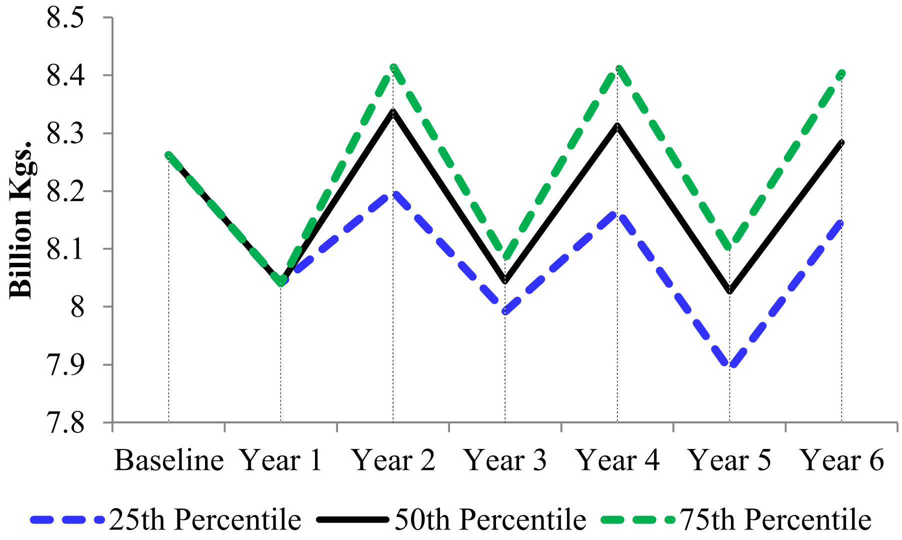


Figure 1.7. Fan graph of retail beef quantity estimates.

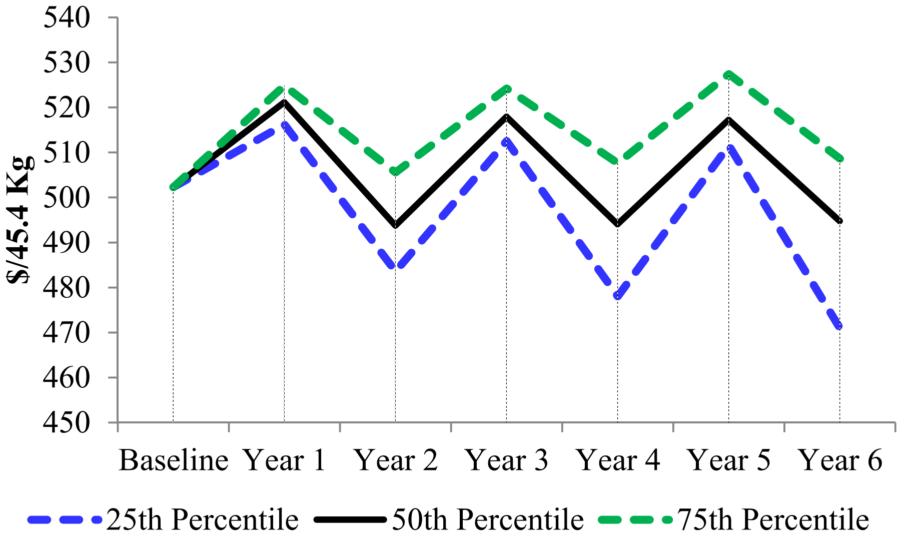


Figure 1.8. Fan graph of retail beef price estimates.

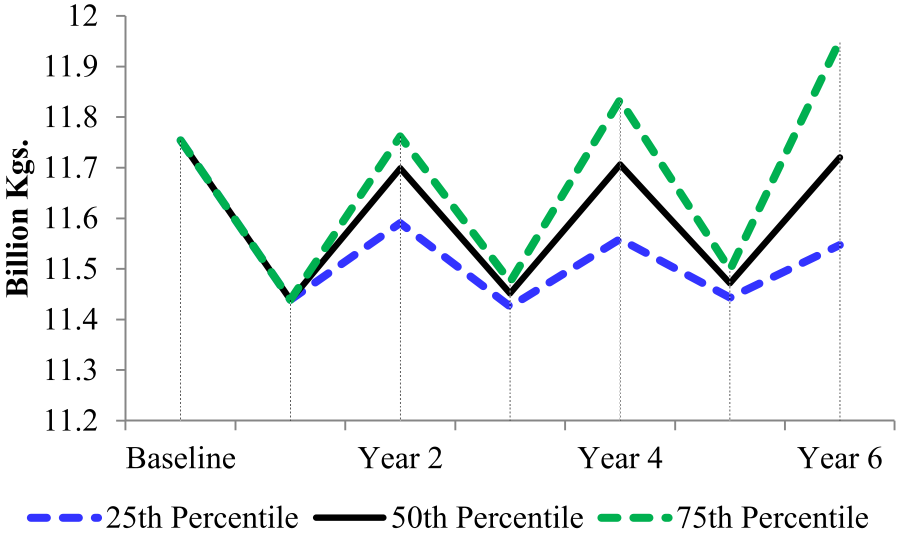


Figure 1.9. Fan graph of packer beef quantity estimates.

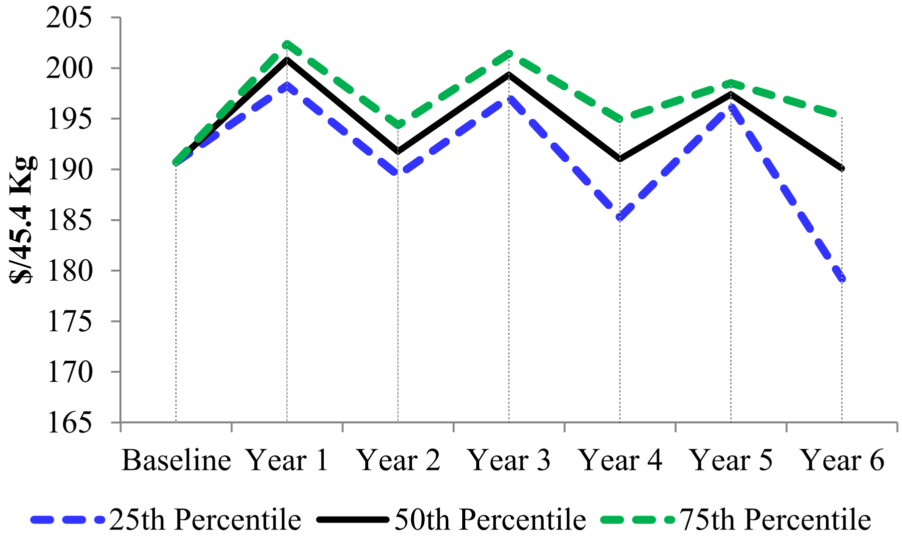


Figure 1.10. Fan graph of packer beef price estimates.

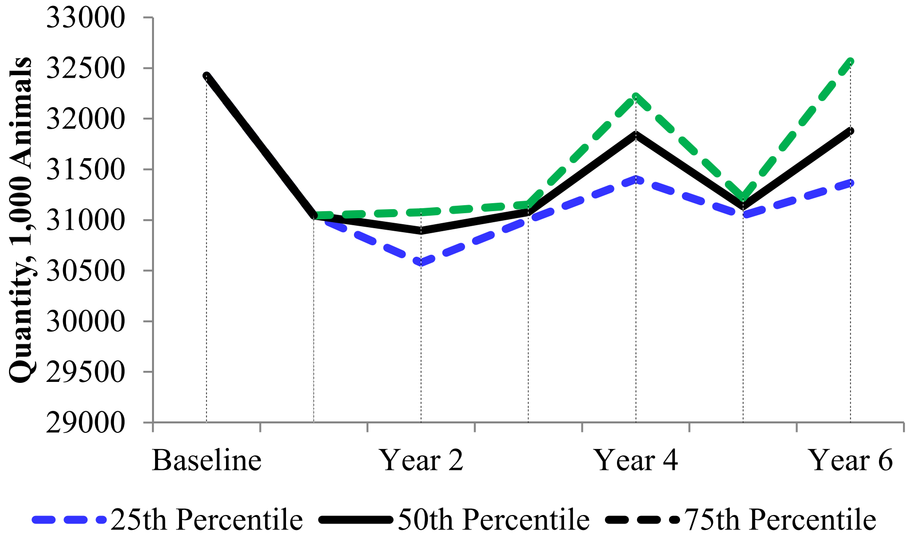


Figure 1.11. Fan graph of fed cattle quantity estimates.

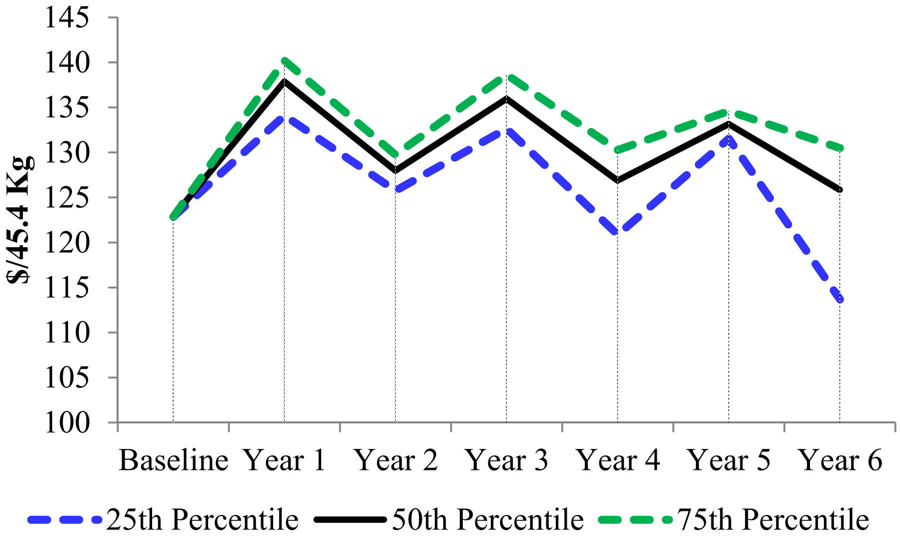


Figure 1.12. Fan graph of fed cattle price estimates.

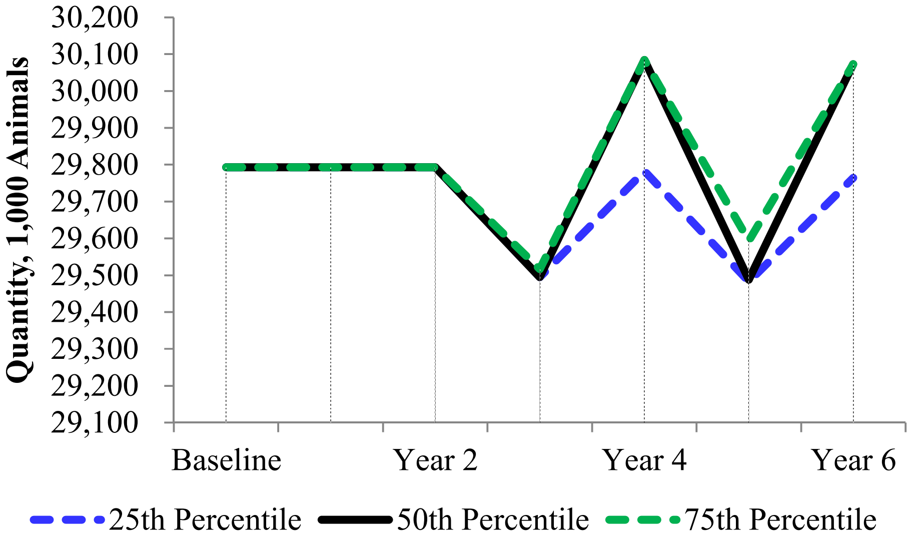


Figure 1.13. Fan graph of feeder cattle quantity estimates.

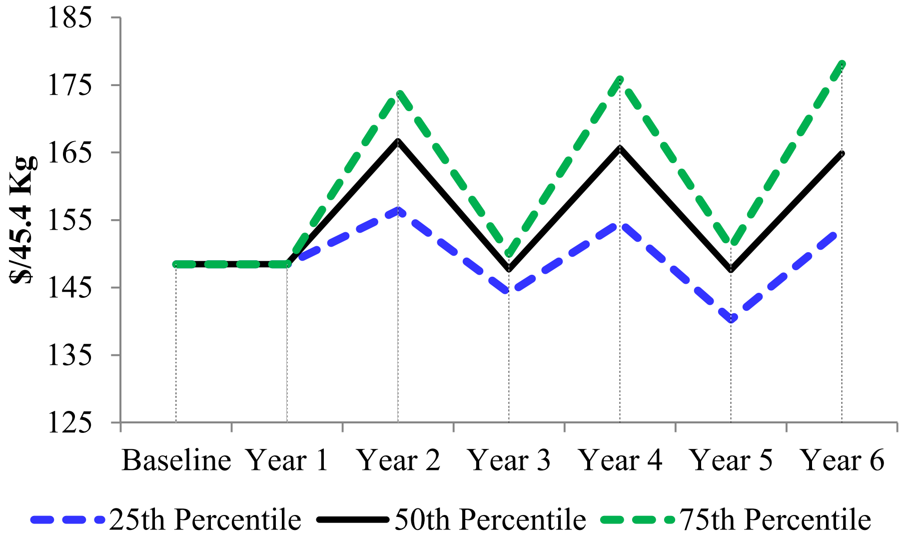


Figure 1.14. Fan graph of feeder cattle price estimates.

APPENDIX B

CHAPTER III SUPPLEMENTAL MATERIAL

Tables

Table 2.1. Supply and Demand Elasticity Definitions and Simulated Estimates of Mean, Standard Deviation, Coefficient of Variation, Minimum, and Maximum.

Elasticity Definition	Mean	Standard Deviation	Coefficient of Variation	Minimum	Maximum
Own-price Elasticity of Demand for Retail Beef	-0.841	0.269	-31.948	-1.848	-0.450
Own-price Elasticity of Supply for Retail Beef	0.352	0.112	31.948	0.188	0.774
Own-price Elasticity of Demand for Packer Beef	-0.567	0.181	-31.948	-1.246	-0.303
Own-price Elasticity of Supply for Packer Beef	0.274	0.087	31.948	0.147	0.602
Own-price Elasticity of Demand for Packer Beef Imports	-0.567	0.181	-31.948	-1.246	-0.303
Own-price Elasticity of Supply for Packer Beef Imports	1.789	0.572	31.948	0.958	3.932
Own-price Elasticity of Demand for Packer Beef Exports	-0.411	0.131	-31.948	-0.902	-0.220
Own-price Elasticity of Demand for Fed Cattle	-0.291	0.125	-31.948	-0.859	-0.209
Own-price Elasticity of Supply for Fed Cattle	0.254	0.081	31.948	0.136	0.559
Own-price Elasticity of Demand for Feeder Cattle	-0.137	0.044	-31.948	-0.301	-0.073
Own-price Elasticity of Supply for Feeder Cattle	0.215	0.069	31.948	0.115	0.473
Own Price Elasticity of Demand for Retail Pork	-0.675	0.216	-31.948	-1.483	-0.361
Own-price Elasticity of Supply for Retail Pork	0.714	0.228	31.948	0.382	1.569
Own-price Elasticity of Demand for Packer Pork	-0.694	0.222	-31.948	-1.526	-0.372
Own-price Elasticity of Supply for Packer Pork	0.430	0.137	31.948	0.230	0.945
Own-price Elasticity of Demand for Packer Pork Imports	-0.694	0.222	-31.948	-1.526	-0.372
Own-price Elasticity of Supply for Packer Pork Imports	1.379	0.440	31.948	0.738	3.030
Own-price Elasticity of Demand for Packer Pork Exports	-0.870	0.278	-31.948	-1.912	-0.466
Own-price Elasticity of Demand for Fed Hogs	-0.499	0.159	-31.948	-1.096	-0.267
Own-price Elasticity of Supply for Fed Hogs	0.401	0.128	31.948	0.215	0.881

Table 2.1. Continued

Elasticity Definition	Mean	Standard Deviation	Coefficient of Variation	Minimum	Maximum
Own-price Elasticity of Demand for Retail Poultry	-0.284	0.091	-31.948	-0.623	-0.152
Own-price Elasticity of Supply for Retail Poultry	0.176	0.056	31.948	0.094	0.387
Own-price Elasticity of Demand for Packer Poultry	-0.215	0.069	-31.948	-0.473	-0.115
Own-price Elasticity of Supply for Packer Poultry	0.137	0.044	31.948	0.073	0.301
Own-price Elasticity of Demand for Packer Poultry Exports	-0.303	0.097	-31.948	-0.666	-0.162
Cross-Price Elasticity of Demand for Retail Beef with Respect to the Price of Retail Pork	0.120	0.052	43.162	0.050	0.322
Cross-Price Elasticity of Demand for Retail Beef with Respect to the Price of Retail Poultry	0.079	0.045	58.026	0.040	0.285
Cross-Price Elasticity of Demand for Retail Pork with Respect to the Price of Retail Beef	0.228	0.106	46.311	0.100	0.671
Cross-Price Elasticity of Demand for Retail Pork with Respect to the Price of Retail Poultry	0.082	0.122	148.192	-0.050	0.638
Cross-price Elasticity of Demand for Retail Poultry with Respect to the Price of Retail Beef	0.248	0.135	54.260	0.100	0.850
Cross-price Elasticity of Demand for Retail Poultry with Respect to the Price of Retail Pork	0.148	0.166	112.423	0.020	0.907

Table 2.2. Quantity Transmission Elasticity Definitions and Estimates.

Transmission Elasticity Definitions	
Percentage Change in Retail Beef Supply Given a 1% Change in Packer Beef Supply	0.771
Percentage Change in Packer Beef Supply Given a 1% Change in Fed Cattle Supply	0.909
Percentage Change in Fed Cattle Supply Given a 1% Change in Feeder Cattle Supply	1.070
Percentage Change in Packer Beef Demand Given a 1% Change in Retail Beef Demand	0.995
Percentage Change in Fed Cattle Demand Given a 1% Change in Packer Beef Demand	1.090
Percentage Change in Feeder Cattle Demand Given a 1% Change in Fed Cattle Demand	0.957
Percentage Change in Retail Pork Supply Given a 1% Change in Packer Pork Supply	0.962
Percentage Change in Packer Pork Supply Given a 1% Change in Fed Hogs Supply	0.963
Percentage Change in Packer Pork Demand Given a 1% Change in Retail Pork Demand	0.983
Percentage Change in Fed Hogs Demand Given a 1% Change in Packer Pork Demand	0.961
Percentage Change in Retail Poultry Supply Given a 1% Change in Packer Poultry Supply	0.806
Percentage Change in Packer Poultry Demand Given a 1% Change in Retail Poultry Demand	1.035

APPENDIX C

CHAPTER IV FIGURES AND TABLES

Tables

Table 3.1. Demographic Characteristics of Survey Respondents (n=223) and U.S. Population.

Variable	Category	Sample Mean	Sample Std. Dev.	%	U.S.[(a)]	%
Age (years)		33.15	19.26		37.5	
Education	High School Diploma or Less			7.7%		41.2%
	4-year College Degree or Less			61.5%		47.6%
	Graduate Courses or More			30.8		11.2%
Household Size (Number of Individuals)		2.49	1.32		2.63	
Gender	Female			55.2%		50.8%
	Male			44.8%		49.2%
Marital Status	Married			42.5%		47.9%
	Not Married			57.5%		52.2%
Household Income ($/year)		$53,824	$25,271		$73,767	

[a] Source: U.S. Census Bureau, 2013 American Community Survey

Table 3.2. Fatty acid composition of sirloin steak from grain-fed, PEAR-fed, and grass-fed steers (g/100 g fatty acid methylesters).

Item	Fatty Acid	Grain-fed	PEAR-fed	Grass-fed	SE
14:0	Myristic	2.14	2.77	2.61	0.212
14:1	Myristoleic	0.30	0.32	0.42	0.049
16:0	Palmitic	25.45^{a}	28.24^{b}	28.05^{b}	0.752
16:1	Palmitoleic	2.11^{a}	2.28^{a}	2.63^{b}	0.112
18:0	Stearic	16.12^{a}	15.94^{ab}	13.90^{b}	0.699
18:1c9	Oleic	37.36^{ab}	34.99^{a}	39.10^{b}	1.188
18:1c11	Cis-Vaccenic	1.29	1.21	1.40	0.108
18:2	Linoleic	5.11	5.07	3.69	0.689
18:3	α-linolenic	0.30	0.36	0.31	0.029
20:1	Gondoic	0.07	0.08	0.12	0.038
20:2	Eicosadienoic	0.04^{ab}	0.04^{a}	0.00^{b}	0.012
20:4	Arachidonic	1.11	1.01	0.95	0.223
22:1	Erucic	0.00	0.01	0.00	0.002
20:5	Eicosapentaenoic	0.09^{a}	0.06^{a}	0.00^{b}	0.019
24:1	Nervonic	0.00^{a}	0.02^{b}	0.00^{a}	0.006
22:6	Docosahexaenoic	0.00	0.01	0.00	0.002

^{a,b} = significant difference ($P < 0.05$)

Table 3.3. Tasting survey ratings of like/dislike for overall, overall flavor, beefy flavor, and juiciness of steak samples from grain-fed, PEAR-fed, and grass-fed cattle.

Characteristic Like/Dislike[1]	Grain-fed	PEAR-fed	Grass-fed	SE
Overall	6.42^{a}	6.33^{a}	5.56^{b}	0.171
Overall Flavor	6.43^{a}	6.32^{ab}	5.92^{b}	0.171
Beefy Flavor	6.52^{a}	6.25^{ab}	6.04^{b}	0.169
Juiciness	5.94^{a}	6.70^{b}	5.34^{c}	0.191

^{a,b,c} = significant difference ($P < 0.05$)

[1] 1 equals extremely dislike while 9 equals extremely like.

Table 3.4. Food Expenditures and Other Characteristics of Interest of Survey Respondents.

Variable	Tasting Respondents			No Tasting Respondents		
	Sample Mean	Sample Std. Dev.	%	Sample Mean	Sample Std. Dev.	%
Household Size (Number of Individuals)	2.81	1.45		2.25	1.16	
Income	$51,823	$27,359		$55,386	$23,646	
Weekly Food Expenditures	$142.09	$110.43		$125.38	$81.80	
Food Expenditures as a Percentage of Income			14.26%			11.77%
Weekly Meat Expenditures	$36.08	$22.51		$36.20	$28.56	
Meat Expenditures as a Percentage of Income			3.62%			3.39%
Weekly Beef Expenditures	$21.47	$15.55		$19.86	$16.68	
Beef Expenditures as a Percentage of Income			2.15%			1.86%

Table 3.5. Mixed logit parameter estimation results.

	Tasting Respondents	No Tasting Respondents	Tasting Respondents	No Tasting Respondents
Variable	Parameter[1]	Parameter[1]	Parameter[1]	Parameter[1]
	Constant Parameter Estimates		Standard Deviation of Random Parameters	
No Product	-3.37***	-1.59***		
	(0.18)	(0.13)		
PEAR-fed	-0.09	-0.49***	0.42***	0.41***
	(0.07)	(0.07)	(0.07)	(0.08)
Grass-fed	-0.14*	0.38***	0.55***	0.64***
	(0.08)	(0.07)	(0.08)	(0.16)
Not Tender	-1.44***	-0.89***	0.45***	0.61***
	(0.10)	(0.08)	(0.09)	(0.08)
Extremely Tender	0.93***	0.59***	0.12	0.20***
	(0.07)	(0.06)	(0.12)	(0.07)
Quality Grade Prime	0.24***	-0.03	0.47***	0.32***
	(0.07)	(0.06)	(0.07)	(0.07)
Quality Grade Select	-0.31***	-0.04	0.44***	0.02
	(0.07)	(0.05)	(0.07)	(0.08)
Imported	-0.49***	-0.57***	0.29***	0.23***
	(0.07)	(0.06)	(0.08)	(0.09)
Local	0.26***	0.30***	0.03	0.04
	(0.05)	(0.05)	(0.06)	(0.09)
No Hormones or Antibiotics	0.23***	0.98***	0.54***	1.12***
	(0.07)	(0.10)	(0.08)	(0.10)
Hormones	-0.02	-0.52***	0.31***	0.47***
	(0.07)	(0.08)	(0.10)	(0.09)
Price	-0.85***	-1.85***	0.53***	1.09***
	(0.09)	(0.23)	(0.07)	(0.10)
No. Observations	6,860	9,132		
Participants	96	126		
Log Likelihood	-1,592.41	-2,205.94		

[1] Single (*), double (**), and triple (***) asterisk are used to denote significance at the 0.10, 0.05, and 0.01 levels, respectively. Standard errors are listed below each estimate in parentheses.

Figures

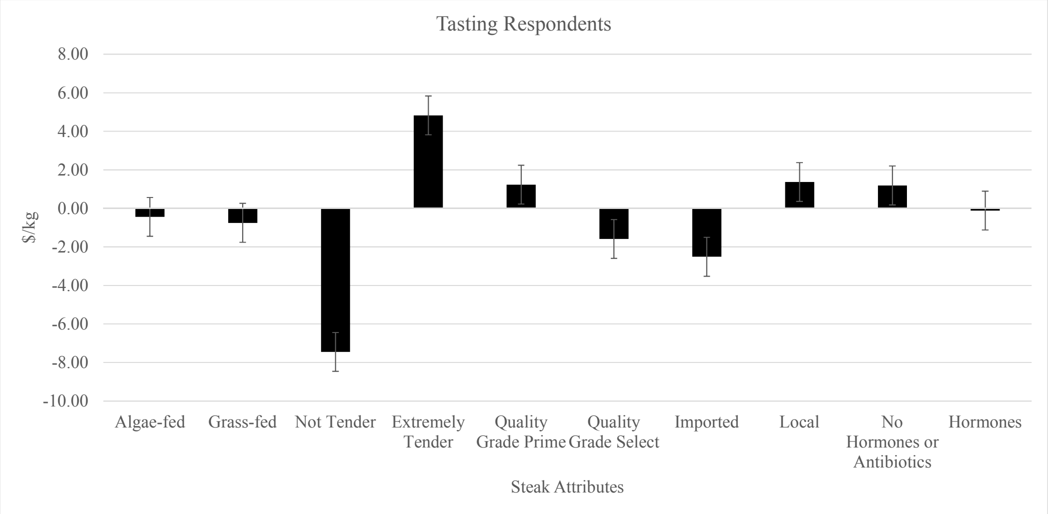


Figure 3.1. Willingness-to-pay estimates in dollars per kilogram for beef attributes. Error bars represent the standard error or the estimates.

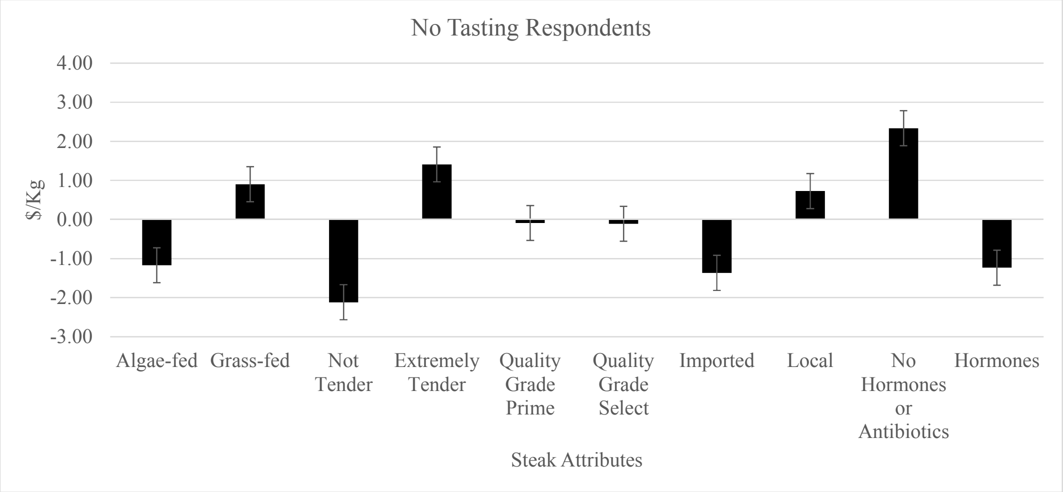


Figure 3.2. Willingness-to-pay estimates for no tasting respondents in dollars per kilogram for beef attributes. Error bars represent the standard error or the estimates.

APPENDIX D

CHAPTER IV SUPPLEMENTAL MATERIAL

Product Attribute Descriptions

1) Production Method

All cattle were raised on pastures (grass) for approximately 18 months.

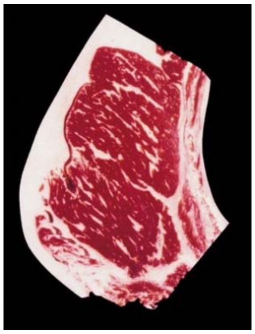
- **Grain-finished Beef -** After pasture, cattle entered a feedlot where they ate a grain based diet.
- **Grass-finished Beef** - Cattle remained on pasture for the rest of their life, until harvested.
- **Algae-finished Beef** - After pasture, cattle entered a feedlot where they ate a grain based diet. Their grain based diet contained an algae-meal component, replacing dried distillers' grain, both byproducts from biofuel production.

2) **Tenderness** in beef is defined as being easily able to chew the piece of beef.

- **Not Tender** - A properly prepared steak was difficult to chew and failed to provide a positive eating experience.
- **Tender** - A properly prepared steak was easily chewed and provided a positive eating experience.
- **Extremely Tender** - A properly prepared steak was very easily chewed and provided an extremely positive eating experience.

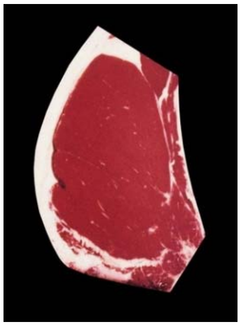
3) Quality Grade

A quality grade is a composite evaluation of factors that affect the tenderness, juiciness, and flavor of beef. Beef grade is based on degree of marbling.



Prime

Choice



Select

- **Prime -** Marbling is moderately abundant.
- **Choice -** Marbling is modest.
- **Select -** Marbling is slight.

4) **Origin**

- **USA** - Cattle were raised, fed, and harvested within the U.S.A.
- **Local** - Cattle were raised, fed, and harvested within a 400 mile radius of the retail location.
- **Imported** - Cattle were raised, fed, and harvested internationally.

5) **Growth Technology**

- **None** - No hormones or antibiotics were used in the production of this animal.
- **Hormone** - Hormones were administered to these animals to promote their growth within the guidelines set by the U.S. Food and Drug Administration (FDA).
- **Antibiotic** - Antibiotics were administered to these animals whenever they displayed symptoms of illness within the guidelines set by the U.S. Food and Drug Administration (FDA).

6) **Price**

- The price of the beef is \$3.00/lb, \$5.00/lb or \$7.00/lb (\$6.61/kg, \$11.02/kg, or \$15.43/kg).

Table 4.1. Willingness-to-Pay estimates in dollars per kilogram for beef attributes.

	Tasting Respondents		No Tasting Respondents	
Variable	Mean WTP[1]	Range WTP[2]	Mean WTP[1]	Range WTP[2]
PEAR-fed	-0.44[3]	[-1.15, 0.26]	-1.17	[-1.61, -0.73]
Grass-fed	-0.75[3]	[-1.54, 0.07]	0.90	[0.51, 1.28]
Not Tender	-7.45	[-9.59, -5.34]	-2.12	[-2.80, -1.43]
Extremely Tender	4.83	[3.40, 6.26]	1.41	[0.99, 1.83]
Quality Grade Prime	1.23	[0.46, 2.01]	-0.09[3]	[-0.33, 0.18]
Quality Grade Select	-1.59	[-2.38, -0.82]	-0.11[3]	[-0.33, 0.13]
Imported	-2.51	[-3.42, -1.63]	-1.37	[-1.79, -0.93]
Local	1.37	[0.75, 1.98]	0.73	[0.44, 1.01]
No Hormones or Antibiotics	1.19	[0.40, 2.01]	2.34	[1.65, 3.02]
Hormones	-0.11[3]	[-0.77, 0.57]	-1.23	[-1.68, -0.82]

[1] Indicates that the range of the 95% confidence interval of WTP includes zero.

[2] Calculated using the delta-method using Taylor's approximation series with a 95% confidence interval.

[3] Indicates that the WTP values are not significant at the 0.05 level.

APPENDIX E

CHAPTER V FIGURES AND TABLES

Tables

Table 5.1. Variables collected from ten feedlots for analysis.

Variable	Description of Variable
Animal Type	Steer/Heifer
Risk Code	High Risk/Low Risk
Location	Feedyard Location
Beta Agonist	None, Optaflexx, Zilmax
In Weight	Average weight of lot upon arrival to feedyard
Out Weight	Average weight of lot when leaving the feedyard
Year	Year of week of record
Week of Year	Week number of year
Weeks to Kill	Weeks until cattle go to abattoir
Lot ID Number	Unique identification number for the lot
Dry Matter Intake	Pounds per day
Current Week Deaths	Number of deaths during week of record
Previous Weeks Deaths	Number of deaths prior to week of record
Respiratory Previous Weeks Deaths	Number of deaths prior to week of record due to respiratory reasons
Digestive Previous Weeks Deaths	Number of deaths prior to week of record due to digestive reasons
Musculoskeletal Previous Weeks Deaths	Number of deaths prior to week of record due to musculoskeletal reasons
Other Previous Weeks Deaths	Number of deaths prior to week of record due to other reasons
Previous Morbidity	Number of animals treated for health reasons in weeks prior to that of record
Total Head Days for Feedyard	Sum of head days for all lots in feedyard
Days in week	Number of days in the week for week of record
Head Days in Lot	Head days of lot, i.e. 70 animals in a lot for 1 day is 70 head days
Days on Feed	Number of days the lot of cattle has been on feed at the feedyard
Placement Date	Calendar date of when cattle were placed into the feedyard
Precipitation	Total precipitation (in) for the week of record
Snowfall	Total snowfall (in) for the week of record
Absolute Maximum Temperature (°F)	Absolute maximum temperature (°F) across the ten feedlots for week of record

Table 5.1. Continued

Variable	Description of Variable
Average Maximum Temperature (°F)	Average of maximum temperatures (°F) across the ten feedlots for week of record
Absolute Minimum Temperature (°F)	Absolute minimum temperature (°F) across the ten feedlots for week of record
Average Minimum Temperature (°F)	Average of minimum temperatures (°F) across the ten feedlots for week of record
Average Temperature (°F)	Average of average temperatures (°F) across the ten feedlots for week of record
Maximum Temperature Range (°F)	Temperature range using absolute maximum and minimum temperatures (°F) for week of record
Average Temperature Range (°F)	Temperature range using average maximum and minimum temperatures (°F) for week of record
Average Wind Speed (Mph)	Average of average wind speed (Mph) across the ten feedlots for week of record
Maximum Wind Speed (Mph)	Average of maximum wind speeds (Mph) across the ten feedlots
Maximum Wind Gust (Mph)	Average of maximum wind gusts (Mph) across the ten feedlots

Table 5.2. Iterative model estimations of number of deaths per week in a feedlot.

	Explanatory Variables																																		
Model Iteration	A[1]	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
1	X[2]	O	O	X	X			O	X	X	X	X			X	X		X	O	X	X															
2	O			X	X			X	X	X	O	O			X	X		X		X	O															
3	X			X	X			X	X	X	X	O			X	X		X		X						X										
4	X			X	X	X		X	X	X	X	X			X	X		X																		
5	X			X	X	O		O	X	X	O	O			X	X		X		X	X	O														
6								X	X	X	X	X	X					X		X						X										
7								X	X	X	X	X	X					X		X						X			X							
8								X	X	X	O	X	X					X		X	X	O	O						O							
9								X	X	X		X	X					X		X	X			X	X					X	X					
10								X	X	X		X	X					X		X	X			X	X					X	X			O	X	X
11								X	X	X		X	O					X		X	X			X	X					X	X				X	X
12								X	X	X		X						X		X	X			X	X					X	X				X	X
13								X	X	X		X						X		X	X			X	X			X		O	X				X	X
14								X	X	X		X						X		X	X			X	X			X			X				X	X
15								X	X	X		X						X		X	X			X	X		O				X				X	X
16								X	X	X		X						X		X	X			X	X		X						X		X	X
17								X	X	X		X	X					X		X	X			X	X		X						X			
(Model 1) 18								X	X	X		X	X					X		X	X			X	X							X	X		X	X
(Model 2) 19								X	X	X		X						X		X	X			X	X					X	X				X	X
20							X	X	X	X	O	X						X		X	X			X	X			X		X	O				X	X
21								X	X	X	X	X						X		X	X			X	X					X	O				X	X
22								X	X	X		X						X		X	X			X	X			X		O	X				X	X

Table 5.2. Continued

	Explanatory Variables																																			
Model Iteration	A[1]	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
23							X[2]	X	X	X		X						X		X	X			X	X					X	X				X	X
24								X	X	X	O	X						X		X	X			X	X			O		O	O				X	X
25							O	X	X	X	O	X						X		X	X			X	X					X	O				X	X
(Model 3) 26							X	X	X	X		X						X		X	X			X	X			X		X	X				X	X
27							X	X	X	X	O	X	O					X		X	X			X	X		X					X	O		X	X
28								X	X	X	O	X	O					X		X	X			X	X							X	O		X	X
29								X	X	X		X	X					X		X	X			X	X		O					X	X		X	X
30							X	X	X	X		X	O					X		X	X			X	X							X	X		X	X
31								X	X	X	O	X	O					X		X	X			X	X		O					X	O		X	X
32							O	X	X	X	O	X	O					X		X	X			X	X							X	O		X	X
33							X	X	X	X		X	O					X		X	X			X	X		X					X	X		X	X
34							X	X	X	X		X						X		X	X			X	X							X	X		X	X
(Model 4) 35							X	X	X	X		X						X		X	X			X	X		X					X	X		X	X
36							X	X	X	X		X		X	O	O		X		X	X			X	X			X		X	X				X	X
(Model 5) 37							X	X	X	X		X		X				X		X	X			X	X			X		X	X				X	X
38							X	X	X	X		X			O			X		X	X			X	X			X		X	X				X	X
39							X	X	X	X		X				O		X		X	X			X	X			X		X	X				X	X
40							X	X	X	X		X		X	O			X		X	X			X	X			X		X	X				X	X
41							X	X	X	X		X		X		O		X		X	X			X	X			X		X	X				X	X
42							X	X	X	X		X			O	O		X		X	X			X	X			X		X	X				X	X
(Model 6) 43							X	X	X	X		X		X			X	X		X	X			X	X			X		X	X				X	X

[1] X signifies a statistically significant variable, while O signifies a variable that was not statistically significant

[2] A is trend, B is snowfall, C is snowfall × maximum temperature, D is sine, E is cosine, F is in weight × placement day of the year × DOF × maximum temperature × precipitation, G is out weight, H is in weight, I is precipitation, J is maximum temperature, K is DOF, L is placement day of the year, M is price of feeder cattle, N is previous week percent mortality, O is previous week percent morbidity, P is respiratory mortality as a percent of total mortality, Q is previous week percent mortality squared, R is maximum temperature squared, S is precipitation squared, T is precipitation × maximum temperature, U is in weight × placement day of the year, V is placement day of the year × DOF, W is in weight × DOF, X is placement day of the year squared, Y is in weight squared, Z is in weight × placement day of the year × DOF, AA is number of animals not receiving a β-AA, AB is percent of animals not receiving a β-AA, AC is percent of animals not receiving a β-AA × maximum temperature, AD is percent of animals not receiving a β-AA × out weight, AE is percent of animals not receiving a β-AA × DOF, AF is number of animals not receiving a β-AA × out weight, AG is number of animals not receiving a β-AA × DOF,

AH is price of feeder cattle × placement day of the year, AI is price of feeder cattle × DOF, and AJ is price of feeder cattle × in weight

Table 5.3. Linear regression model parameter estimates.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
F Value	65.55	74.80	67.62	64.39	64.68	63.17	99.92
Adjusted R Squared	0.59	0.61	0.62	0.60	0.62	0.63	0.45
Intercept	-10,282.00	-10,761.00	-17,716.00	-15,738.00	-16,731.00	-160,39.00	971.06
In Weight[1]	31.57	33.22	40.39	34.06	39.55	38.01	
Out Weight			3.62	3.56	3.15	3.03	
Placement Day of the Year	1.40	1.28	1.49	1.47	1.47	1.41	
Precipitation	147.02	147.55	155.02	151.71	160.21	153.40	
Maximum Temperature	-7.08	-7.27	-6.30	-7.09	-6.61	-7.25	-1.18
Feeder Price	-9.11						
Maximum Temperature^2	12.09	12.56	10.56	11.85	11.26	12.22	
Precipitation × Maximum Temperature	-391.36	-395.81	-411.20	-402.14	-422.25	-399.28	
In Weight × Placement Day of the Year	9.02E-05	7.09E-05	6.37E-05	7.17E-05	5.02E-05	3.83E-05	
Placement Day of the Year^2	-4.15E-03	-3.83E-03	-4.38E-03	-4.31E-03	-4.36E-03	-4.11E-03	
In Weight^2	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-1.30E-03
Number of Animals Not Receiving β-AA				0.01			
Number of Animals Not Receiving BA × DOF	1.232E-05			1.74E-05			
Number of Animals Not Receiving BA × Out Weight	-9.65E-07			-8.22E-06			
Percent of Animals Not Receiving β-AA			4,101.94		3,505.20	3,582.10	
Percent of Animals Not Receiving β-AA × DOF		7.15	8.43		9.15	7.30	-3.02

Table 5.3. Continued

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Percent of Animals Not Receiving β-AA × Out Weight		-0.77	-3.97		-3.60	-3.57	
Feeder Cattle Price × DOF	-0.09	-0.11	-0.11	-0.11	-0.12	-0.11	-0.04
Feeder Cattle Price × In Weight	0.03	0.02	0.06	0.02	0.01	0.02	0.01
Previous Week Mortality Percentage					3,763.10	15,926.00	
Previous Week Mortality Percentage^2						-506,405.00	

[1] All beta coefficients are statistically significant at the 5% or less level.

Table 5.4. Non-linear regression model parameter estimates.

	Poisson Model	Negative Binomial Model 1	Negative Binomial 2
Log-Likelihood Value	-5,835.86	-3,354.29	-3,355.04
Intercept	-42.35	-38.55	-36.63
In Weight[1]	0.10	0.10	0.09
Out Weight	0.01	0.09	0.01
Placement Day of the Year	0.01	0.05	0.01
Precipitation	0.41	0.44	0.43
Maximum Temperature	-0.02	-0.03	-0.03
Maximum Temperature^2	0.04	0.05	0.05
Precipitation × Maximum Temperature	-1.05	-1.13	-1.12
In Weight × Placement Day of the Year	1.77E-07	1.71E-07	1.70E-07
Placement Day of the Year^2	-1.60E-05	-1.44E-05	-1.40E-05
In Weight^2	-8.48E-05	-7.97E-05	-7.46E-05
Percent of Animals Not Receiving β-AA	13.14	12.00	12.52
Percent of Animals Not Receiving β-AA × DOF	0.01	0.01	
Percent of Animals Not Receiving β-AA × Out Weight	-0.01	-0.01	-0.01
Feeder Cattle Price × DOF	-2.25E-04	-1.95E-04	-1.50E-04
Feeder Cattle Price × In Weight	3.24E-05	2.95E-05	0.000023825
Previous Week Mortality Percentage	54.06	57.07	59.61
Previous Week Mortality Percentage^2	-1,619.40	-1,876.76	-2,013.03

[1] All beta coefficients are statistically significant at the 5% or less level.

Table 5.5. Model forecast evaluation values for the entire dataset, high death dataset, and low death dataset. Bolded values are the lowest values for the row.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Poisson Model	Negative Binomial Model 1	Negative Binomial Model 2
Entire Dataset										
MAPE[1]	17.13	16.97	17.39	17.22	17.27	16.72	21.14	15.31	**15.13**	15.16
MAD[2]	48.29	**27.56**	48.07	48.04	47.61	46.52	57.59	43.14	43.27	43.35
MSD[3]	4,810.80	4,652.27	4,522.36	4,658.85	4,462.07	4,352.90	6,663.25	4,036.48	4,075.96	**3,923.58**
High Death Dataset										
MAPE	24.77	24.27	22.97	23.65	22.81	22.82	31.61	**21.86**	23.03	46.96
MAD	155.73	150.70	142.29	147.67	141.03	141.22	195.59	**133.38**	140.61	277.61
MSD	27,893.61	25,741.89	32,654.54	**24,578.54**	32,051.16	32,697.86	53,261.51	29,825.11	32,705.27	91,642.58
Low Death Dataset										
MAPE	25.04	25.24	27.01	25.48	26.90	24.05	38.26	23.24	23.70	**23.07**
MAD	36.03	35.98	38.38	36.82	38.45	34.60	53.37	33.01	33.50	**32.65**
MSD	1,803.73	1,704.54	1,938.34	1,963.21	2,082.50	1,818.61	3,912.81	1,690.22	1,622.77	**1,605.32**

[1] MAPE stands for mean absolute percentage error

[2] MAD stands for mean absolute deviation

[3] MSD stands for mean squared deviation

Table 5.6. Trigger values for switching to the high death models.

Trigger Variables	Trigger Values
Maximum Temperature	< 44
Placement Day of the Year	> 221
Maximum Temperature Squared	< 14
Percent of Animals Not Receiving a β-AA × DOF	< 78
Feeder Price × In Weight	> 79,530
Previous Week Mortality Percentage Squared	> 0.000132

Table 5.7. Trigger values for switching to the low death models.

Trigger Variables	Trigger Values
In Weight	< 665
In Weight × In Date	< 24,438,645
Percent of Animals Not Receiving a β-AA	> 0.96
Out Weight	< 1,230
In Weight Squared	< 442,660
Percent of Animals Not Receiving a β-AA × Out Weight	> 1,175
Percent of Animals Not Receiving a β-AA × DOF	> 98
Feeder Price × In Weight	< 64,580

Figures

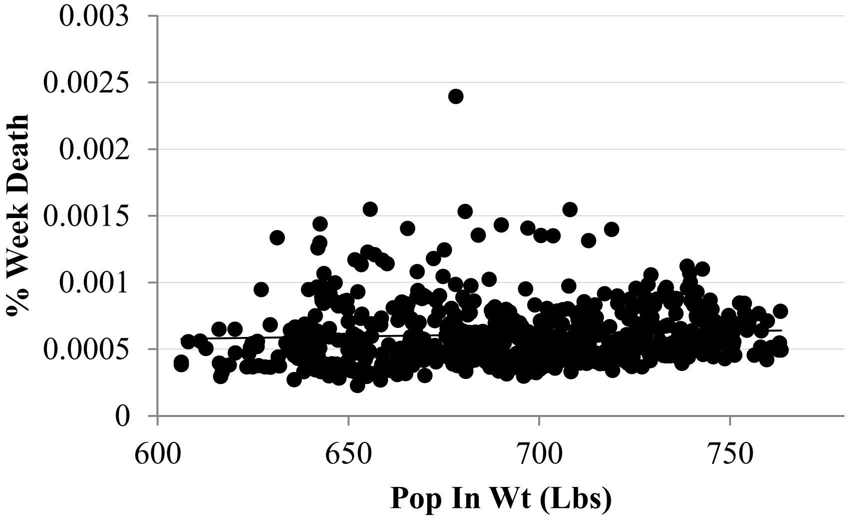


Figure 5.1. Scatter plot comparing number of week deaths and in weight.

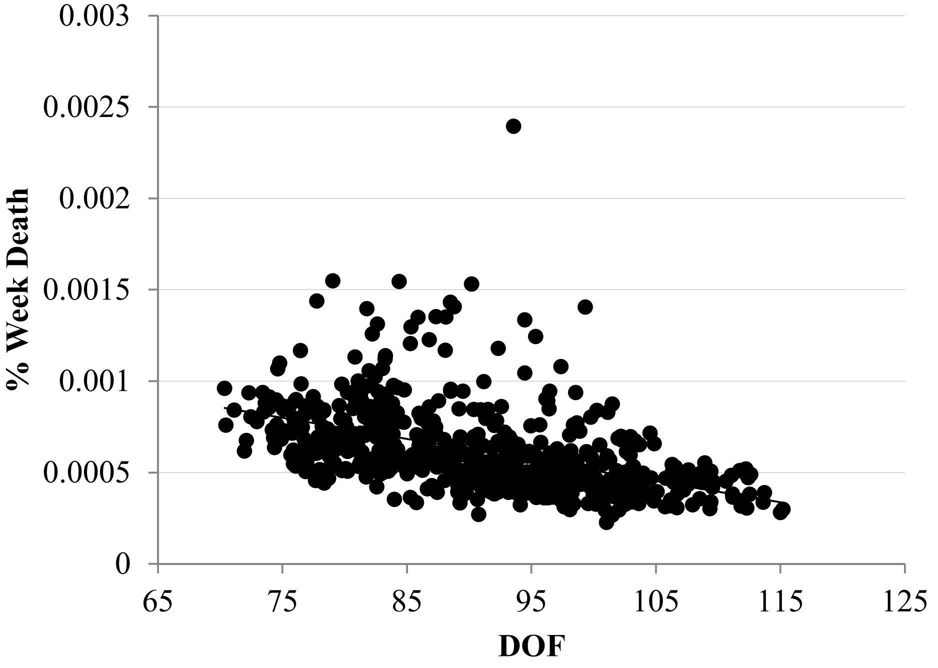


Figure 5.2. Scatter plot comparing number of week deaths and days on feed.

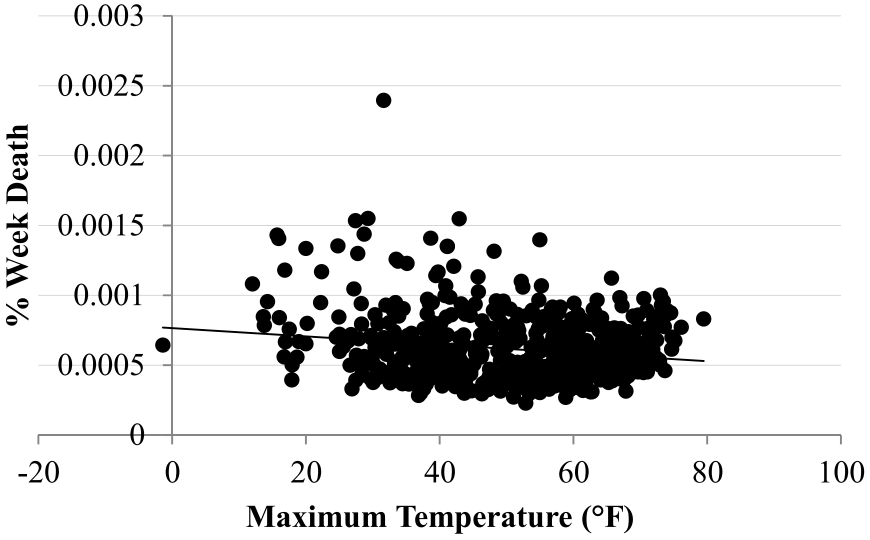


Figure 5.3. Scatter plot comparing number of week deaths and maximum temperature.

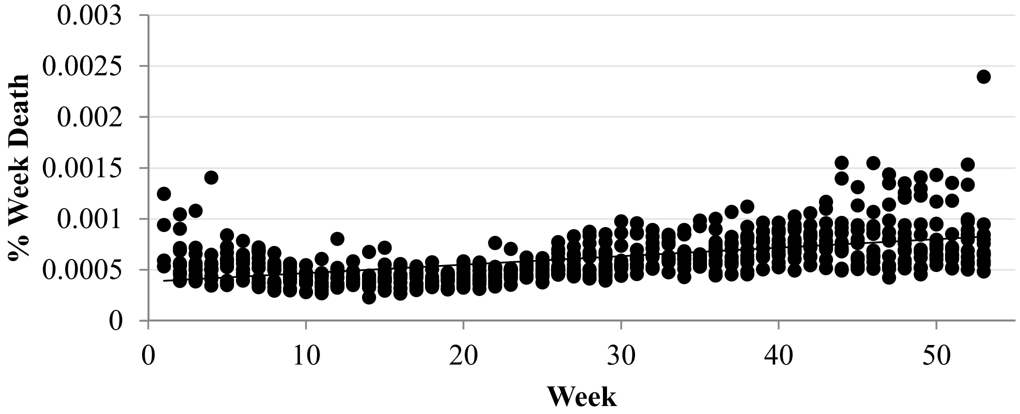


Figure 5.4. Scatter plot comparing number of week deaths and week of year.

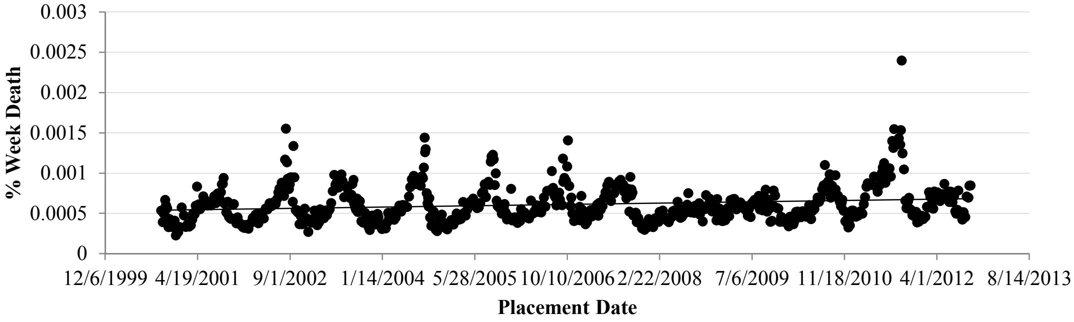


Figure 5.5. Scatter plot comparing number of week deaths and placement date.

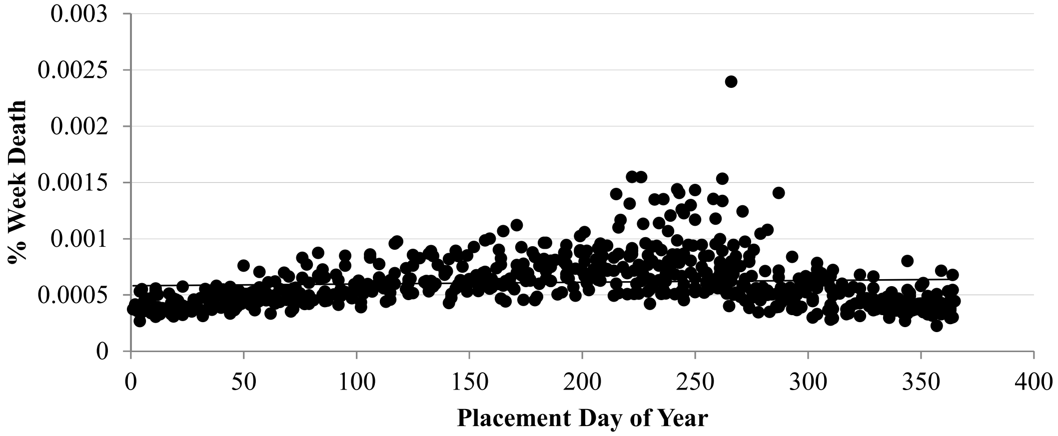


Figure 5.6. Scatter plot comparing number of week deaths and placement day of year.