EFFECT OF ETHOXYQUIN SUPPLEMENTATION ON THE HEALTH, PERFORMANCE AND CARCASS CHARACTERISTICS ON NEWLY RECEIVED AUCTION ORIGIN HEIFER CALVES

By

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FORMAT OF THESIS

This Thesis is presented in the Journal of Animal Science style format, as outlined by the Oklahoma State University graduate college style manual. The use of this format allows the independent chapters to be suitable for submission to scientific journals.

CHAPTER I

INTRODUCTION

In 1999 over 33 million calves were marketed in the U.S. alone (Sparks Companies Inc., 2000). In many cases our marketing and management systems expose calves to the stress of new environments and experiences, which can result in decreased performance and increased morbidity. Morbidity and mortality of calves associated with Bovine Respiratory Disease (BRD) are estimated to cost the U.S. beef industry $500 million annually (NASS, 1996). Factors contributing to the cost of BRD include death loss, treatment costs, lowered feed efficiency, decreased daily gain, and increased labor in the feedlot (Loerch and Fluharty, 1999). Improper management of calves pre- and post-weaning can be a "recipe for disaster". Most problems occur because of the structure of the cattle industry. Cattlemen who raise and sell calves are not often compensated for the pre-weaning and post-weaning steps necessary to prepare a calf for its next journey in life. Smith, et al (1988) stated that most young calves are not prepared to withstand the challenges of marketing systems and other stressors. In a short period of time, calves are exposed to a long list of stressors and that cumulatively contribute to the "recipe for a sick calf" (Stokka, 1998). This causes many problems upon arrival into a receiving yard or a commercial feedlot. Most health problems occur within the first two weeks following arrival (Loerch and Fluharty, 1999), which can overload management's ability to keep costs down and performance up (Smith et al., 1988). Increased morbidity during the receiving period is also related to carcass quality. Stovall et al (2000) found that increased numbers of treatments for BRD during the receiving period can cost as much as $37 at harvest more than 200 days later. Much research has been directed towards finding new ways of deceasing morbidity and mortality of newly received feedlot cattle. Proper function of the immune system is necessary to resist infectious diseases. Of all the stressors and negative influences, which can suppress the immune system, dietary nutrients are the most easily regulated. Vitamins A, E, and C and Se and Zn have shown to enhance disease resistance in mammals (Nockels, 1986) and in cattle (Nockels, 1988). Eng (1992) reported that trace minerals have also increase disease resistance in cattle. Vitamin E has been shown to decrease morbidity in newly received stocker and feedlot cattle (Gill et al., 1986; Hays et al., 1987). Although Vitamin E supplementation has been shown to be useful, the cost of supplementing 500 IU per day of Vitamin E during a 42-day receiving period is approximately $0.40 to $0.50 per head which is a concern to some producers. Ethoxyquin, a mixture that contains 6-ethoxy-1, 2-dihydro-2, 2,4-trimethylquinoline and other chemicals produced by Solutia, Inc., St. Louis MO, is used widely in the feed industry as an antioxidant. We investigated the usefulness of this product in diets of recently received, lightweight calves.

The following review of literature provides information on the causes and management of sickness, as well as the function of an antioxidant. A detailed review of the compound ethoxyquin is included as well.

CHAPTER II

LITERATURE REVIEW

The "recipe for a sick calf"

Stressors. Selye (1976) described biological stress as "the nonspecific response of the body to any demand". Stress can be comprised of many different factors that can cumulatively lead to a decreased ability to respond to pathogens or harmful tissue injuring substances. Weaning and the subsequent 30-day post-weaning period is perhaps the most stressful time in a calf's life. Calves experience stress when separated from the cow (Pirelli and Zollinger 1991) and additional stress if they are also transported to market in the immediate post-weaning period. Transportation may have a negative impact on the calves' immune system. Some studies have shown an increase of morbidity and mortality during the first couple of weeks post-transport (Knowles 1995; Mackenzie et al., 1997). Other research, however, suggests that transportation may be additive to the many other stress factors (Von Tungeln, 1986; Cole et al., 1988). Trunkfield and others (1990) noted that the way in which calves are handled during the loading and unloading process are the most stressful parts of transportation, however the journey characteristics and vehicle condition are also important. Ribble (1995a) found distance shipped had no effect on morbidity, although commingling of animals before and/or after arrival into feedlots was associated with the onset of BRD in calves (Alexander, 1989; Ribble 1995b). The constant mixing and moving of animals between groups into strange environments will expose calves to new pathogens. Placing calves into overcrowded high spatial density areas with non-immune heavy shedding animals can lead to compromise of the calf's defense systems (Hancock 1984; Klingborg, 1986). These multiple stress factors cumulatively have a negative impact on the calves physiological, metabolic, and behavior responses. Loerch and Fluharty (1999) stated that stress has its most significant impact on feed intake due to the behavioral characteristic of the calf and immunocompetency upon arrival into the feedyard. In order for an infectious disease to occur, there must be an imbalance between the animals defense system, the agent causing the disease (bacteria, virus, etc.) and stress factors (Klingborg 1986).

Cellular response

When an animal senses a potential threat, the body produces adrenaline (Brunner, 1989), which can suppress the immune system. In a review, Brunner (1989) reviewed reports showing a rise in corticosteriod levels in calves exposed to stress, which coincided with reduced lymphocyte activity and increased vulnerability to infection. Nockels and others (1996) found that epinephrine induced reactions can lead to formation of free radicals that cause lipoperoxidation, which is damaging to the immune system. Free radicals are defined as "an atom or group of atoms possessing an unpaired electron" (Lehninger et al., 1993), which are highly reactive. The free radicals superoxide

($O_2^{\cdot -}$), peroxy radical ($ROO^{\cdot}$), and hydroxyl radical ($HO^{\cdot}$) are produced in normal cellular activities (Weiss and LoBugio, 1982). Although not a free radical, hydrogen peroxide (H_2O_2) is also highly reactive. Freeman and Crapo (1982) found that free radicals can attack certain targets resulting in disruptions in membrane integrity, eicosanoid synthesis, DNA structure, energy production, and protein function. Fortunately, free radical production within the cell may be controlled by antioxidants or through enzymes capable of destroying them.

Nutritional effects

Supplementing the diet with antioxidants has been one method proposed to combat poor performance, sickness, and mortality of stressed cattle. Nutrition plays an important role in the development and function of the immune system (Sheffy, 1981; Beisel, 1982). Nutritional management of the immune system may reduce sickness, therefore decreasing the need for treatment with antimicrobials. As mentioned earlier, dietary nutrients can be more easily regulated than the many other stressors that have a negative impact on the immune system. Extensive research has shown that certain supplemental vitamins (Nockel, 1986; Nockel, 1988), minerals (Nockel, 1986) and trace minerals (Eng, 1992; Chirase, 2000) can improve cattle's ability to resist infectious disease. These immunomodulating nutrients may be needed not only to enhance specific facets of the immune response, but also to protect tissues from the damage of free radicals produced by phagocytic cells that are actively combating infections (Nockels, 1988). Of the many different vitamins and minerals used to decrease sickness, vitamin E has received the most attention.

Gill and others (1986) found that supplementing newly received calves with vitamin E decreased morbidity rates by 13.4% and increased weight gain. Vitamin E enhances both the cell-mediated and humoral immunes response (Reddy et al., 1986) by influencing the function of certain immune cells (Smith et al., 2000), thereby decreasing calf morbidity and mortality. Sufficient intake of vitamin E must coincide with/or precede high stress (Gill et al., 2000). Galyean and others (1999) suggested that nutritionists should consider the physical and physiological stage of newly received stressed beef calves to compensate for decreased intake and known nutrient deficiencies. If a calf is in a positive energy balance and gaining weight soon after arrival, it can better resist disease challenge (Loerch and Fluharty, 1999).

Ethoxyquin

Ethoxyquin was first discovered in 1921. Throughout the years, many different names and abbreviations have been used to describe this compound. In this review it will be identified as ethoxyquin and Agrado™ (Solutia, Inc.). This aromatic amine exists in a partially nitroxide free radical form which is presumed to be formed by the dissociation of the hydrogen atom (point **a** of Figure 1) from the secondary amine moiety. This particular characteristic may be responsible for the antioxidant activity of ethoxyquin. Ethoxyquin is commercially available in two forms: concentrated form (90% pure) and salt form (25 – 65 2/3% pure). The concentrate form is clear and is a strong refractive oily liquid (base). Once exposed to air, oxidation changes the color of the compound from clear to an opaque reddish-black color. The salt form is derived from the base through further processing. It ranges in color from a fine white crystal to a light tan crystalline substance. This powdery form containing the chemical and carrier (60% active ingredient) was the form used in our trials.

Historically, ethoxyquin was used widely in the feed industry as a preservative of carotenes and vitamin E in dehydrated alfalfa meal. In the food industry, the compound is not used as a preservative; however, it is often used to "promote color retention" in paprika and ground chili pepper, using a maximum concentration of 100 ppm (Willis, 1998). It is also used to prevent scab and scald on apples and pears (Krumsiek, 1998). The maximum allowable residue in eggs, meat, poultry, apples, pears, poultry fat and liver for human consumption is 0.5 ppm (Willis, 1998). The compound is also one of the components in the memory-enhancing drug hydergine (Healthlink). On the animal side, ethoxyquin can be added to premixes and manufactured feeds at the maximum level approved by the U.S. Food and Drug Administration (150 ppm or .015%) to reduce lipid oxidation and preserve vitamins A and E. Ethoxyquin is commonly included into poultry rations (125 ppm in ration) to enhance skin pigmentation (Bailey et al., 1996). In the pet food industry, ethoxyquin has been used to prevent rancidity of fats in pet foods. Gross and others (1994) found that ethoxyquin and butylated hydroxyanisole (BHT) prevented peroxide formation during a 16-week storage period when added to the diet. The maximum level approved for canines is 75 ppm. Krumsiek (1998) reviewed two papers showing that ethoxyquin increased the oxidative stability of milk when fed to dairy cows, however, an unidentified foreign compound was present in the milk. Knowing the strict regulations of milk quality, Krumsiek concluded that ethoxyquin should not be fed to lactating cows. When ethoxyquin was fed to lambs at 0.1% in a pelleted diet for 12 weeks, a residual compound presumed to be ethoxyquin was found in triceps muscle, suggesting that ruminal metabolism of ethoxyquin may be insufficient (Demille, 1972).

Measurement. Ethoxyquin is excreted rapidly in the feces, making it difficult to measure ethoxyquin in the cells of animals. The measurement of glutathione, a tripeptide comprised of glycine, glutamate, and cysteine, has often been used to determine the biological effects of ethoxyquin. Glutathione has the ability to remove toxic peroxides that form under aerobic oxidation during growth and metabolism. Other methods to determine ethoxyquin concentration include direct measurement with high-pressure liquid chromatography (HPLC); measurement of response in concentration of thiobarbituric acid (TBA), an index of malonaldehyde accumulation that appears during lipid oxidation; and glutathione. Radioactively labeled ethoxyquin (^{14}C) has also been used to monitor its metabolism.

Levels. Krumsiek (1998) reviewed the different levels of ethoxyquin fed to different species and their responses. When ethoxyquin was fed to 60 to 100 kg (132 to 220 lb) cattle at 250 mg/kg body weight, and consumption of feed was at 2.5% body weight, peripheral cell necrosis and mid-zone vacuolation of the liver occurred within 48 hours. No negative effects were observed when a ration containing 270 and 2700 ppm of ethoxyquin was fed to calves consuming feed at 3% of body weight for 109 days, although calves consuming the higher concentration eventually refused feed. Feed intake was reduced for 12 hours when poultry were fed ethoxyquin at 2g/kg body weight, however, intake returned to normal after 48 hours. A minimal amount of residue was found in poultry tissues in spite of the increased levels of ethoxyquin, suggesting poultry are more tolerant to higher levels of ethoxyquin than mammals.

Metabolism. In several papers reviewed by Krumsiek (1998), ethoxyquin was found to be readily absorbed from the gut of both mice and rats when fed at 25mg/kg of body weight, however excretion in both urine and feces was rapid. Some tissue accumulation was found in the rat liver, kidney, and adipose tissue, however muscle was not a major depot. Although the parent material was excreted, metabolites were detected. Rat urine contained ethoxyquin in the hydroxylated form and dihydroxylated form, contrasting another study where only ethoxyquin and hydroethoxyquin were found in sheep. This suggested that ruminant metabolism of ethoxyquin is different than that of monogastrics (Krumsiek, 1998). In canines, more than 99% of the ethoxyquin consumed is eliminated through urine (Wilson and Deeds, 1959). Because ethoxyquin is rapidly removed from the body, and muscle is not a major depot, it is safe to conclude that the meat from animals fed a diet supplemented with up to 150 ppm of ethoxyquin should not have any harmful effect on humans.

Ethoxyquin and cattle

Agrado™ is the trade name of the compound ethoxyquin, owned by Solutia Inc., St. Louis, MO. Initial studies of the ethoxyquin antioxidant in cattle diets began in 1997 by Dr. Fred Owens at Oklahoma State University. Owens concluded that, "Agrado™ (ethoxyquin) would produce similar if not better results than high levels of vitamin E". Recent research has shown that ethoxyquin improves ration stability, nutrient utilization, cattle performance, cattle health, and end-product value. Following is a review of the effects of feeding ethoxyquin to beef cattle on receiving health and feedlot performance, finishing performance, carcass characteristics, liver abscess rate, and end-product value.

Receiving health and performance. Kegley and Hellwig (1997,1998) conducted two experiments to determine if supplementing calves with ethoxyquin (150 ppm) during the backgrounding period had any relationship with performance. In both experiments, diets consisted mainly of cracked corn, cottonseed hulls, and soybean meal. During experiment one, 96 head of weaned heifer calves (206 kg; 454 lbs) were fed ethoxyquin during a 42-day receiving period. Heifers fed ethoxyquin had a significantly reduced ($P<.05$) morbidity rate (83.3% vs. 72.9%, for control vs. ethoxyquin fed calves, respectfully) and medication cost ($P<.05$) compared to control calves. Calves fed ethoxyquin had improved average daily gain, feed intake, and feed efficiency. In experiment two, 86 mixed breed bull and steer calves (237 kg; 522 lbs) were also fed 150 ppm of ethoxyquin in the diet during a 41-day receiving period. No differences were found in morbidity or medical costs. Ethoxyquin fed calves had an increased ($P<.03$) gain/feed ratio during the last 28 days of the trial, however no differences were found in overall feedlot receiving performance. Because results of studies have been inconsistent, more research is needed in this area.

Finishing/Carcass performance. The first ethoxyquin feeding trial on beef cattle was done using 135 ppm of ethoxyquin in the finishing diet during the last 28 days of feeding. Krumsiek and Owens (1997) used 75 yearling British cross cattle (327 kg; 720 lbs) to evaluate the effects of supplemental ethoxyquin during the finishing period. Diets consisted mostly of ground corn, alfalfa pellets and a supplement. Calves supplemented with ethoxyquin gained 3.26 lbs per day while controls gained 3.09 (P=.64). Feed efficiency (7.65 lbs vs. 6.92 lbs, P=.19, for control vs. ethoxyquin fed cattle, respectfully) was not statistically different. No differences were found in carcass traits. However, calves fed ethoxyquin did have a more desirable (brighter red) lean maturity score (P<.02) and higher yield grades (P<.04). Ethoxyquin reduced the incidence of liver abscesses by 52% (4.4% vs. 6.7% for ethoxyquin vs. control fed cattle, respectfully), although differences were not significant. At a Colorado research feedlot (Anonymous, 1998), 128 cross-bred yearling steers (351 kg; 773 lbs) were fed a diet for 123 days containing 150 ppm of ethoxyquin to re-evaluate the effects of ethoxyquin on feedlot performance and carcass characteristics. The diet consisted of steam-flaked corn, corn silage, soybean meal, condensed corn distillable solubles and fat. No differences were found in feedlot performance or carcass characteristics. The liver abscess rate was lower for ethoxyquin fed cattle, although was not significantly different. Green and others (1999) conducted a trial at the Texas A&M University Agricultural Research and Extension Center at Amarillo to evaluate feedlot performance, carcass response and antioxidant capacity of beef steers fed diets containing 150 ppm of ethoxyquin during pre-conditioning and finishing periods. Treatments included pre-transit treatments (ethoxyquin vs. control) vs. post-transit treatments (ethoxyquin vs. control). Pre-transit treatment had no effect on post-transit performance. Finishing diets consisted of steam-flaked corn, fat, cottonseed hulls and supplement. Bull and steer calves (n=80; 264 kg; 582 lbs) were fed for 182 days. Serum samples from calves fed ethoxyquin pre-transit had decreased vitamin E concentrations compared to calves not fed ethoxyquin. Although vitamin E concentrations were similar pre- and post-transit for the calves not fed ethoxyquin, ethoxyquin feeding increased vitamin E concentrations post-transit. Average daily gain of calves supplemented with ethoxyquin was 44% higher (P<.05) during the last 14 days of feeding; overall average daily gain (3.21lbs vs. 3.56 lbs, P<.01 for control vs. ethoxyquin fed calves, respectfully) was also increased. No differences were found in feed efficiency. Hot carcass weights were higher (P<.05) when calves were fed ethoxyquin, however no other differences were found in other carcass traits. Another finishing trial was conducted in Texas (Anonymous, 1999) to evaluate growth performance, health response and carcass characteristics of beef cattle with or without 125 IU or 150 IU of vitamin E and(or) 150 ppm of ethoxyquin. Cross-bred steers (n=2830; 327 kg; 720 lbs) were fed steam-flaked corn, high-moisture corn, alfalfa hay, corn silage, and fat. Treatments included: (1) 0/0, no supplemental vitamin E or ethoxyquin in finishing diet; (2) 125/0, 125 IU vitamin E/day and no ethoxyquin; (3) 125/150, 125 IU vitamin E/day + 150 ppm ethoxyquin/day; (4) 500/0, 500 IU vitamin E/day and no ethoxyquin; (5) 500/150, 500 IU vitamin E/day + 150 ppm ethoxyquin/day. Among these treatments, intake was decreased (P<.05) when calves were supplemented with higher levels of vitamin E and ethoxyquin. Calves supplemented with high levels of vitamin E + ethoxyquin (Trtmt 5) gained less weight than calves in other treatments. Lower gain was partially the result of reduced feed intake. Feed efficiency was increased (P<.09) when calves were fed supplemental vitamin E and supplemental ethoxyquin as compared to the control diet. No differences were found in carcass traits. Cost of gain (P<.03) and breakeven selling price (P=.02) were higher for calves fed the 500 IU vitamin E + ethoxyquin diets compared to 125 IU vitamin E + ethoxyquin diets. Researchers concluded that supplementation with 125 IU/day vitamin E or 500 IU/day vitamin E + ethoxyquin improves returns by almost $6.00/head compared with steers fed the control diet. No significant differences were found in liver abscess rate between treatments.

Nelson and others (1999) fed diets contained 150 ppm ethoxyquin and either 150, 500 or 1000 IU vitamin E. Cattle fed ethoxyquin + 150 IU vitamin E had 33% more carcasses grading U.S. Choice, however no difference were found in other carcass traits. Ethoxyquin has had have positive effects on gain, however it tends to decrease feed intake while increasing feed efficiency. Effects on carcass merit are minimum and inconsistent.

End product. The first case-life study was a continuation of the Krumsiek and Owens (1997) ethoxyquin finishing trial. Their results suggested that feeding ethoxyquin to beef cattle resulted in increased case-life for ground beef (6 d vs. 2 d, for ethoxyquin vs. control, respectfully) and ribeye steaks (4 d vs. 3 d, for ethoxyquin vs. control, respectfully). The difference in color was more dramatic for ground beef than ribeye steaks. Ethoxyquin also reduced rancidity by decreasing oxidative degradation of ground beef. This was determined by measuring the accumulation of thiobarbituric acid reducing substances (TBARS), which measures the level of rancidity or lipid oxidation. The higher the TBARS value the more oxidative degradation occurs, which is detrimental to meat desirability (particularly off-flavor). Walenciak and others (1998) found similar results, showing significant decrease in TBARS values in strip steaks and ground beef. Ethoxyquin delayed rancidity by 3 days. However, in this trial cattle were fed 150 ppm for 123 days whereas Krumsiek and Owens (1997) fed 135 ppm ethoxyquin for the last 28 days of feeding. Nelson and others (1999) compared various levels of vitamin E with ethoxyquin and found no differences in case-life for strip steaks or ground beef across all treatments. Although, L*[a] values were higher for those steaks from cattle receiving 150 IU vitamin E + ethoxyquin, the percent discoloration for both strip steaks and ground beef was similar for all treatments. TBARS values for cattle fed 500 IU and 1000 IU + ethoxyquin were noticeably lower for ground beef. These results suggest that fresh meat from cattle fed ethoxyquin can consistently have a less undesirable rancid taste.

[a] Light value used to measure muscle discoloration

CHAPTER III

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CHAPTER IV

EFFECT OF ETHOXYQUIN SUPPLEMENTATION ON THE HEALTH, PERFORMANCE AND CARCASS CHARACTERISTICS OF NEWLY RECEIVED AUCTION ORIGIN HEIFER CALVES

T.C. Stovall, D.R. Gill, H. Han, J. T. Wagner and R.L. Ball

ABSTRACT

Nine hundred six mixed breed heifer calves (193 kg; 427 lb average initial body weight) were fed a diet containing the antioxidant ethoxyquin, to determine the effect on rate and efficiency of gain, and response to medical treatments. Each load of cattle was blocked by weight; within each weight block cattle were assigned to one of two diets (0 or 150 ppm added ethoxyquin) resulting in eight pens per load. All cattle, purchased at auction markets in Oklahoma and Arkansas by order buyers, were given free choice access to a moderately high energy receiving diet (51.35 Mcal NEg/cwt). Health and performance were monitored for 42 days following arrival. Diets were supplemented with 15 IU vitamin E/kg and either 0 or 150 mg ethoxyquin/kg. Cattle were observed for signs of sickness daily and frequency, duration, and extent of medical treatments were recorded. Four hundred six of the heifers were followed through commercial feedlots to harvest to determine any carry-over effects from ethoxyquin supplementation during the receiving period on finishing performance and carcass characteristics. Heifers fed supplemental ethoxyquin that became sick required fewer medical treatments for recovery, suggesting supplementing

the diet with ethoxyquin may reduce medical costs during the receiving period. Ethoxyquin supplementation did not influence the rate and efficiency of gain during the 42-day receiving trial period. Supplementation with ethoxyquin during the receiving period did not result in any significant ($P<.05$) carry-over effects on finishing performance or carcass characteristics.

Introduction

Supplementing newly received cattle with vitamin E, an antioxidant, in the diet has been shown to improve daily gain, feed efficiency, and reduce sickness during the receiving period (Hays et al., 1987; Gill et al., 1986; Gill et al., 2000). Looking for a lower cost alterative to vitamin E, Krumsiek and Owens (1998) explored the usefulness of supplementing the diet of feedlot cattle with ethoxyquin. They reported that supplementation with ethoxyquin tended to increase the rate and efficiency of gain as well as positively effecting lean maturity (brighter red). Other trials have verified the positive effects of supplementation with ethoxyquin on the rate (Anonymous, 1998; Green et al., 1999) and efficiency of gain (Anonymous, 1998; Anonymous, 1999). However, the effect of supplementation with ethoxyquin during the finishing period on carcass traits still remains inconsistent. Nelson and others (1999) found that cattle fed ethoxyquin had 33% more U.S. Choice carcasses than cattle not fed ethoxyquin. Most of the data shows that ethoxyquin has a minimal effect on carcass traits (Anonymous, 1998; Green et al., 1999; Anonymous, 1999). Kegley and Hellwig (1997 and 1998) conducted two trials to determine the effect of supplementation with ethoxyquin during the feedlot-receiving period on the health and performance response of newly weaned calves. In experiment one, they found a significant ($P<.05$) decrease in sickness and medical costs when calves were supplemented with ethoxyquin. In experiment two, no differences were found in health performance, however, calves fed ethoxyquin had a significantly ($P<.03$) increased gain/feed ratio as well as increased gain during the last 28 days of the trial. The consistency of outcomes when calves are fed ethoxyquin during the receiving period still remains questionable. The objective of this trial was to evaluate the effect of ethoxyquin supplementation during a 42-day receiving period on the health, performance and carcass characteristics of stressed newly received heifer calves.

Materials and Methods

Nine truck loads (trials) of cattle, purchased by order buyers from auction markets in Oklahoma and Arkansas, were shipped to the Willard Sparks Beef Research Center at Stillwater, OK. Arrival weight, number of head, cattle origin, arrival date, and transit shrink for each load are summarized in Table 1. Upon arrival at the feedlot, each load of calves was uniquely identified with a numbered ear tag and weighed individually. Cattle were then placed into a large pen and offered free choice long-stem prairie hay and water overnight. During the morning after arrival, cattle were processed as follows:

1. Individual weights recorded;
2. Cattle were vaccinated with BRSV VAC 4®, Bayer Corp. (Bovine Rhinotracheitis Virus; Bovine Virus Diarrhea Virus; Parainfluenza-3 Virus; Bovine Respiratory Syncytial Virus), IM; Vision 7® Bayer Corp. (Clostridium chauvoei, septicum, novyi, sordellii and perfingens types C

and D), SQ; and treated for internal and external parasites using Cydectin®(moxidectin), Fort Dodge Animal Health, a pour-on;

3. Heifers were treated with an antibiotic if clinical signs of illness were detected;
4. A hospital card was initiated for calves diagnosed as sick;
5. Allocated to treatments (ethoxyquin supplementation vs. no ethoxyquin supplementation, respectfully) based on arrival weight;

Cattle were blocked into two weight groups and assigned into eight pens holding 10 to 16 animals each. Pens measured 40x100 foot and had fence line cement feed bunks. Fence line waterers were shared by adjacent pens. Calves were revaccinated with BRSV VAC 4® 14 days post-arrival.

Treatment. Cattle were fed a common starter ration, (Tables 2 and 3) during the 42 day receiving period that was balanced to NRC(1996) recommendations. Fifteen IU of vitamin E / kg was supplemented to all heifers. Ethoxyquin was included in the supplement at 0 or 150 ppm using a corn-based premix. One hour before feeding (0830), trained personnel determined the amount of feed to be offered that day. Ethoxyquin was supplemented during the 42-day receiving period only.

Health Management. After processing, cattle were checked once daily for clinical signs of illness, primarily Bovine Respiratory Disease (BRD). Animals had to show at least two of the following clinical signs of disease before it could be removed from the pen and taken to the hospital for evalution: depression; lack of fill; occasional soft cough; physical weakness (knuckling, or altered gait); ocular or nasal discharge. A subjective severity of illness score (slight, moderate, or severe) was assigned while the calf was still in the home pen.

Calves meeting the above criteria were taken to the hospital where the rectal temperature was determined. If the rectal temperature exceeded 104°F and had two or more of the clinical signs described above, the animal was considered "sick". Sick animals were treated based on a specified sequence of antimicrobial drugs shown in Table 4. If the calf failed to respond to the first treatment or relapsed, it was treated with the second drug in the sequence. If it failed to respond to the second treatment or relapsed a second time, it was treated with the third drug in the sequence. Following medical treatment heifers were returned to their original pens. All information was recorded on an individual "sick card". During the 42-day receiving period, heifers that were chronically ill and / or severely lame were removed from the experiment. All calves which died were necropsied at the Oklahoma Animal Disease Diagnostic Laboratory. Medical records from the commercial feed yard were not available.

Cattle Weighing. Heifers were weighed (individual and platform by pen) on days 0, 14, 28, and 42 of the trial. At the end of the 42-day receiving period the cattle were taken off feed and water approximately 16 hours before the last weight was taken. Cattle were transported to commercial feed yards within seven days of completing the 42-day receiving period. Hot carcass weight was determined at harvest.

Finishing performance and carcass data collection. We were able to trace 406 head (Loads 1-7) through the feedlot and collect feedlot performance and carcass. Final live weight (FINALWT) was calculated by dividing the hot carcass weight by .645 (average actual dressing percentage for these lots). Feedlot gain

(LOTADG) was determined from shrunk body weight at the end of the receiving period (42-d wt) to final live weight. Overall average daily gain (TOTALADG) was calculated from the start of the receiving period to final live weight. Average days on feed were approximately 198 days. Heifers were harvested at the Farmland National Beef Inc. facility at Liberal, KS. Farmland personnel collected individual U.S.D.A. carcass data through the Farmland carcass data service. All data were sent to Oklahoma State University for summary and analysis.

Results

Receiving-feedlot Performance. Performance of the cattle that gained more than 0.25 lb./day is summarized in Table 5. There were no differences in average daily gain between treatment groups during any time period. Supplementation with ethoxyquin did not significantly affect DMI. There were no differences in the gain/feed ratio between treatment groups.

Receiving health Performance. The influence of ethoxyquin on health and morbidity is summarized in Table 6. Ethoxyquin decreased overall sickness from 69 to 62% (P=0.06). Since most of the cattle were detected as sick in the first 5 days, before a feed additive could have an effect, the data were further analyzed excluding cattle that become sick in the first 5 days. When the cattle were detected as sick in the first 5 days were excluded, ethoxyquin reduced the average number of medical treatments (1.03 vs. 1.18 for ethoxyquin vs. control cattle, respectively) needed to cure the first illness.

Finishing performance. Final weights and gains of cattle classified by treatment during the receiving period are presented in Table 7. No differences were found in finishing performance.

Carcass characteristics. No significant differences were found in carcass characteristics due to ethoxyquin supplementation during the receiving period (Table 8).

Discussion

In this trial, ethoxyquin supplementation of the receiving diet was shown to have a positive effect on minimizing the number of treatments to cure BRD in beef calves. This would support other results (Kegley, 1997; Anonymous, 1999) suggesting ethoxyquin could reduce medical costs. No other significant differences were detected.

When comparing diets used in other ethoxyquin feeding trials (Anonymous, 1998; Anonymous, 1999; Green, 1999; Kegley, 1997 and 1998; Krumsiek, 1997; and Nelson, 1999) much variation was noted, suggesting ration composition could influence the outcome. If the dietary ingredients had a minimal amount of processing, then much of the natural antioxidants, i.e. vitamin E, would remain in the diet and be available to the animal. This may explain why in this study, ethoxyquin supplementation resulted in minimal benefits. The ration contained whole corn (unprocessed) and wheat-midds, which contribute a lot of natural vitamin E to the diet. An additional 12.4 IU/kg of natural vitamin E was discovered when calculating the potential contribution from each major ration ingredient. Therefore, if the diet already had high levels of vitamin E, we wouldn't expect a positive effect from additional antioxidant supplementation. This could explain why Krumsiek and Owens (1997) found very positive benefits from supplementing with additional ethoxyquin, since the main source of energy in their diet was ground corn. It is possible that processing corn and exposure to summer heat may have destroyed the natural antioxidants. Therefore diets used in earlier ethoxyquin feeding trials could have been low in vitamin E, resulting in positive results when a supplemental antioxidant was supplied. Supplementation with ethoxyquin may not be beneficial in all feeding systems and with all types of diets. It is important to evaluate the total antioxidant status of the diet when considering supplementation strategies. Further study is needed to determine what dietary ingredients might benefit from supplemental antioxidants.

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Figure 1. Presumed chemical structure of ethoxyquin (Krumseik, 1998)

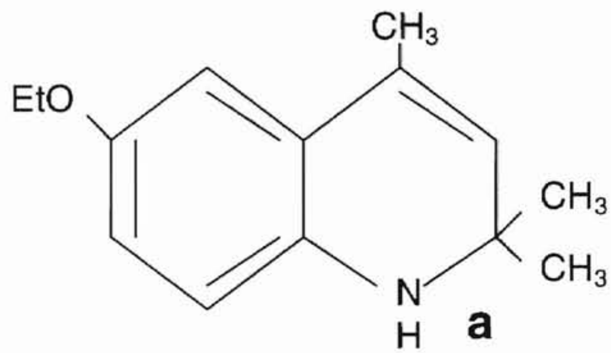

Table 1. Origin, arrival date, number of head, arrival weight, and in transit shrink for each load of cattle.

Trial	Origin	Arrival Date	Number of Head	Arrival Wt., lb.	% Shrink
1	OK	9-10-98	90	472	1.1
2	OK	9-20-98	92	471	1.0
3	OK	9-29-98	90	472	1.0
4	OK	10-05-98	79	510	1.0
5	OK	10-29-98	111	383	1.0
6	OK	11-04-98	125	378	1.0
7	AK	11-21-98	103	418	1.0
8	AK	1-22-99	108	386	1.0
9	OK	1-23-99	108	400	1.0

Table 2. Composition of diets on a dry matter basis.

Ingredient	Ethoxyquin	Control
Soybean hulls	32.5	32.5
Supplement [a]	30.5	30.5
Corn dent NO 2	25.0	25.0
Cotton seed hulls	10.0	10.0
Premix [b]	2.0	-
Premix [c]	-	2.0

[a] Supplement composition: wheat midds 54.37%, cotton seed meal 24.59%, soybean meal(47.5%) 11.48%, limestone 3.6%, salt 0.88%, selenium-600 0.033%, and cane molasses 4.9%; Rumensin was added to provide 22 g/ton of ration and vitamin A was added to provide 2500 IU/lb of ration.

[b] Premix composition: ground corn 87.375%, ethoxyquin 1.25%, soybean meal 10%, $CaCO_3$ 1.5%.

[c] Premix composition: ground corn 88.5%, soybean meal 10%, $CaCO_3$ 1.5%.

Table 3. Calculated composition of diet.

	Ration composition		Supplement Composition	
Nutrients	DM %	As Fed %	DM %	As Fed %
NEm, mcal/cwt	82.00	74.09	75.08	75.08
NEg, mcal/cwt	51.35	45.95	46.91	46.91
Crude Protein, %	15.21	13.61	27.58	24.55
Crude Fiber, %	21.13	18.91	8.42	7.49
K, %	1.11	0.99	1.61	1.43
Ca, %	0.74	0.66	1.78	1.58
Phos., %	0.45	0.41	1.02	0.91
Dry Matter, %	100.00	89.48	100.00	89.59

Table 4. Sequence of drugs (veterinarian prescribed).

Treatment	Drug	Amount mL/cwt	Administered
NO. 1	Micotil (tilmicosin)	1.5	SQ
NO. 2	Nuflor (florfenicol)	6.0	SQ
NO. 3	Excenel (ceftiofur)	2.0	SQ

Table 5. Least squares means of receiving-feedlot performance for heifers supplemented with 0 or 150 ppm of ethoxyquin.

Item	Ethoxyquin	Control	P
Liveweight, lb [a]			
Initial	427.40	427.63	.89
Final	518.54	519.63	.71
ADG, lb.			
Day 0 to 14	2.06	1.94	.20
Day 14 to 28	2.39	2.51	.46
Day 0 to 28	2.23	2.22	.93
Day 28 to 42	2.04	2.11	.55
Total [a]	2.16	2.19	.65
DMI, lb.			
Day 0 to 14	7.07	7.00	.61
Day 14 to 28	11.59	11.49	.56
Day 0 to 28	9.33	9.25	.55
Day 28 to 42	13.63	13.65	.88
Total	10.76	10.71	.73
GF, lb [b]			
Day 0 to 14	29.28	27.53	.19
Day 14 to 28	20.75	21.89	.40
Day 28 to 42	14.82	15.39	.54
Total [a]	20.20	20.44	.51

[a] Weight based on shrunk weight
[b] lb. of gain / 100 lb. of feed

Table 6. Effect of ethoxyquin on receiving health performance.

Item	Ethoxyquin	Control	P
Morbidity, % [a]	62	69	.06
Morbidity, % [b]	15	21	.05
Medical treatments[c]	1.03	1.18	.05
Repull [d]	.11	.10	.53
Mortality, %	0.88	1.10	

[a] All cattle included.
[b] Cattle that became sick after fifth day of trial only.
[c] Number of drug treatments required to cure the first illness.
[d] Recovered animals that became sick again.

Table 7. Least squares means of finishing performance for heifers supplemented with 0 or 150 ppm of ethoxyquin.

Trait	Ethoxyquin	Control	SE	P
Initial wt (0 d), lb	464.72	464.72		
Receiving 42-d wt, lb	552.39	554.57	1.9	.41
Final wt, lb	1087.68	1098.71	5.9	.19
LOTADG, lb/d	2.82	2.87	.03	.29
TOTALADG, lb/d	2.69	2.73	.02	.24

Table 8. Least squares means of carcass characteristics for heifers supplemented with 0 or 150 ppm of ethoxyquin.

Trait	Ethoxyquin	Control	SE	P
Hot carcass wt, (HWT) lb	701.55	708.67	3.8	.19
Quality Grade[a]	2.69	2.73	.02	.24
Yield grade	2.41	2.49	.04	.26
% U.S. Choice	57.56	62.67	3.4	.29

[a]Choice = 3.00

APPENDIX A. Comparison of % Morbidity (All Cattle) per load[ab].

Trial (Load)	Ethoxyquin	Control	% change[c]
Load 1	50	68	-26
Load 2	35	64	-45
Load 3	75	67	11
Load 4	71	67	6
Load 5	81	75	7
Load 6	63	63	--
Load 7	73	86	-15
Load 8	64	84	-23
Load 9	41	49	-16

[a] All cattle included in analysis
[b] No differences found (P>.05)
[c] % change from control treatment

APPENDIX B. Comparison of % Morbidity (Excluding first 5 days) per load[ab].

Trial (Load)	Ethoxyquin	Control	% change[c]
Load 1	9	14	-36
Load 2	20	26	-23
Load 3	6	16	63
Load 4	2	5	-60
Load 5	47	53	-11
Load 6	30	36	-17
Load 7	1	5	-80
Load 8	13	17	-23
Load 9	9	17	-47

[a] Data analyzed excluding morbidity the first 5 days
[b] No differences found (P>.05)
[c] % change from control treatment

APPENDIX C. Comparison of number of treatments to cure the first illness (All Cattle)[a].

Trial (Load)	Ethoxyquin	Control	% change[b]
Load 1	1.00	1.03	-3
Load 2	1.07	1.37	-22
Load 3	1.44	1.24	14
Load 4	1.00	1.10	-9
Load 5	1.13	1.23	-8
Load 6	1.09	1.07	2
Load 7	1.35[c]	1.04[d]	22
Load 8	1.09	1.08	.9
Load 9	1.06	1.00	6

[a] All cattle included in analysis
[b] % change from control treatment
[cd] Means within row with different superscripts are different (P< .05)

APPENDIX D. Comparison of number of treatments to cure the first illness (Excluding first 5 days) per load[ab].

Trial (Load)	Ethoxyquin	Control	% change[c]
Load 1	1.00	1.25	-20
Load 2	1.00	1.25	-20
Load 3	1.00	1.41	-29
Load 4	1.00	1.00	--
Load 5	1.17	1.28	-9
Load 6	1.05	1.12	-6
Load 7	Non-est	--	--
Load 8	1.08	1.12	-4
Load 9	1.00	1.00	--

[a] Data analyzed excluding morbidity the first 5 days
[b] No differences found (P>.05)
[c] % change from control treatment

APPENDIX E. Comparison of average daily gain (lb) per load [a].

Trial (Load)	Ethoxyquin	Control	% change[b]
Load 1	1.78	1.91	-7
Load 2	1.89	2.03	-7
Load 3	2.11	2.18	-3
Load 4	2.23	2.32	-4
Load 5	2.37	2.31	3
Load 6	2.39	2.35	2
Load 7	2.13	2.00	6
Load 8	2.29	2.15	6
Load 9	2.45	2.57	-5

[a] No differences found (P>.05)
[b] % change from control treatment

APPENDIX F. Comparison of feed efficiency per load [ab].

Trial (Load)	Ethoxyquin	Control	% change[c]
Load 1	6.48	5.88	9.2
Load 2	5.68	5.27	7.2
Load 3	4.81	4.83	-.4
Load 4	5.14	5.00	2.7
Load 5	4.40	4.49	-2
Load 6	4.36	4.46	-2
Load 7	4.98	5.02	-.7
Load 8	4.80	4.96	-3
Load 9	4.71	4.56	3

[a] Data reported in pounds of feed per 1 pound of gain
[b] No differences found (P>.05)
[c]% change from control treatment

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VITA

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Candidate for the Degree of

Master of Science

Thesis: EFFECT OF ETHOXYQUIN SUPPLEMENTATION ON THE HEALTH, PERFORMANCE AND CARCASS CHARACTERISTICS ON NEWLY RECEIVED AUCTION ORIGIN HEIFER CALVES

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Experience: Raised south of Billings, Montana on a cow/calf, yearling, and farming family ranch; worked summers for my father performing all ranch duties in running a family business.

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