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The effects of functional oils on sensory attributes of beef ribeye steaks

by

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in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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CHAPTER 1. GENERAL INTRODUCTION

Introduction

Consumers of beef today are looking for a natural product that is still highly palatable. With the European Union banning the use of antibiotic ionophores, scientists have been evaluating other alternatives to reduce energy and protein losses in the rumen (Calsamiglia et al., 2007). A solution would be natural products that function similar to ionophores.

Previous work over the last thirty years has evaluated the use of functional oils as a feed additive to inhibit the growth of some bacteria. There are numerous studies on a variety of functional oils to be used as feed additives. The product used in this study, Essential™, is composed of castor oil and cashew nut shell oil. This study is the first in which Essential™ is fed to beef cattle, but it has been previously evaluated as a feed for poultry diets (Torrent, 2007). Other studies have utilized various essential oils in dairy diets (Tassoul and Shaver, 2008; Calsamiglia et al., 2007). However, essential oils have an “essence” that may cause an aversion to the feed (J. Torrent, Oligo Basics, Excelsior, MN, personal communication). Concerns of tenderness and palatability are of utmost importance for consumers to continue to purchase lean beef products, so evaluating the meat quality along with feed conversion efficiencies is very important.

The beef industry has taken advantage of procedures such as electrical stimulation during harvest (Roeber et al., 2000; Savell et al., 1978; Schroeder et al., 1982) and aging post harvest (Gruber et al., 2006; Smith et al., 1978) to improve the palatability of fresh meats.

The main method for the beef industry to measure acceptability of meat is through sensory evaluations of beef post harvest.

This experiment was designed to evaluate an alternative feed additive of natural origin for finishing cattle while maintaining meat quality. The objectives of this research were to determine the eating qualities of ribeye steaks from cattle fed Essential™ and/or monensin during the finishing program. The overall objective was to provide consumers beef products produced by natural products.

Thesis Organization

This thesis is organized into three chapters. The first chapter is a general introduction to the use of functional oils as a feed additive in beef cattle feeding operations and a general literature review of relevant topics pertaining to this research. The second chapter is a manuscript to be submitted to the Journal of Animal Science. The manuscript contains an abstract, introduction, materials and methods, results and discussion, implications and literature cited. The third chapter is a summary of general conclusions of this research.

Literature Review

Meat quality

Genetics, nutrition, and other environmental factors all have an effect on the composition of meat animal carcasses. These same factors affect meat quality. The process of converting muscle to meat can influence meat quality. Handling and conditions immediately prior to harvest is when environment has the greatest impact on meat quality. The pre-harvest environmental stress can come from transportation to market, handling during the marketing process, and immobilization in preparation for harvest. The conversion of muscle to meat influences several aspects of meat quality including, tenderness, juiciness, color, and flavor (Lawrie, 2006). Proportion of fat to lean, attractiveness, color of lean, and price are the most important factors influencing consumer selection of meats (Brady, 1975). Therefore, the beef industry has done many things in an attempt to correct some of the meat quality problems such as implementing electrical stimulation and the aging of meat (Lawrie, 2006).

Palatability

Palatability of meat depends upon such qualities as color, odor, flavor, juiciness, tenderness, and texture (Weir, 1960; Lawrie, 2006). Currently, marbling level is used as a visual indicator of palatability in the beef quality grading system (Killinger et al., 2004). Sensory panel evaluations are often done to fully evaluate the eating and visual quality of meat. However, the individual views and preferences of the consumer are also important in determining eating quality. A study completed by Dransfield et al. (1984) found that Irish and English panels tended to value flavor more highly than tenderness and juiciness, whereas Italian panelists valued tenderness and juiciness higher than flavor. The study also showed

that French and Belgian taste panelists had a preference for the flavor of aged beef from older animals. These studies identify regional differences among palatability.

Juiciness

Juiciness has a great deal to do with the water-holding capacity of meat. Water-holding capacity affects the appearance of the meat before cooking, its behavior during cooking, and juiciness on mastication (Lawrie, 2006). The juiciness of cooked meat can be separated into two effects; the impression of wetness during the first chews produced by the rapid release of meat fluids, and sustained juiciness due to slow release of serum and to the stimulating effect of fat on salivary flow (Weir, 1960).

The sensation of juiciness is related to the amount of intramuscular fat. Thus, well-marbled meat from mature animals with a relatively high degree of finish is juicier than that from young animals with less marbling. Meat from younger animals has a watery effect on first chewing but gives a final impression of dryness (Weir, 1960).

Tenderness and juiciness are closely related. The more tender the meat, the more quickly the juices are released by chewing and the juicier the meat appears (Weir, 1960).

The most important factor influencing juiciness in cooked meat is the cooking procedure. Juiciness usually varies inversely with cooking losses (Weir, 1960). The losses due to shrinkage on cooking are determined by factors such as method of cooking, and time and temperature of cooking. High temperatures will cause protein denaturation and will cause considerable lower water-holding capacity. The high temperatures will melt fat and tends to destroy the structures retaining fat (Weir, 1960; Lawrie, 2006). Meat that is cooked quickly to a set internal temperature has a lower cooking loss and is juicier than that cooked slowly to the same temperature. Grilling and dielectric heating lower the loss of juice also.

It is important to note that the process of freezing does not affect juiciness; however the length of storage time does affect juiciness (Lawrie, 2006).

Tenderness

Tenderness, as shown by numerous consumer studies, is the most important palatability factor in the acceptance of beef (Weir, 1960; Lawrie, 2006). Consumers have indicated that beef tenderness is important to steak quality and that they are willing to pay more for beef products that they know to be tender (Killinger et al., 2004). Most consumer dissatisfaction with beef relates to tenderness (Brady, 1957). In a study done by Barham et al. (2003), steaks from implanted animals were rated lower for initial and sustained tenderness by a trained sensory panel. Seventy-five percent of consumers are willing to pay a premium for tender beef (Barham et al., 2003).

Tenderness to the palate includes texture and involves three aspects: the initial ease of penetration of the meat by the teeth, the ease with which the meat breaks into fragments, and the amount of residue remaining after chewing (Weir, 1960). Connective tissue, myofibril muscle proteins, sarcoplasmic proteins, and sarcoplasmic reticulum in muscle are a few of the determinants of the degree of tenderness (Lawrie, 2006).

Miller et al. (1996) developed a set of critical control points for meat tenderness. The critical control points were selected since they are areas that greatly influence tenderness. They are genetic regulation of beef tenderness, percentage of *Bos indicus* breeding, management of preslaughter-days on high concentrate diet, animal age, rigor mortis-pH decline, chilling rate, electrical stimulation, post-mortem aging, handling, preparation and cooking, degree of doneness, and consumer perception. The goal is to reduce the variability of tenderness and to improve the overall tenderness of beef products.

Age

Since tenderness has a great deal to do with the connective tissue content in general, increasing age connotes decreasing tenderness. This may be explained by the fact that the connective tissue in young animals has less cross-bonding (Lawrie, 2006). Beef from older animals has a greater need for tenderizing procedures (Brady, 1957). Also, with increasing age the proportion of salt and acid-soluble collagens decreases in bovine muscle (Lawrie, 2006).

Sex

Hormonal balances due to differences in sex or to the addition of synthetic hormones during feeding may affect the growth pattern of the animal and hence carcass and meat characteristics. The castration of male animals alters the hormonal balance and changes the growth pattern in such a manner that they fatten more readily (Weir, 1960). Bryce-Jones et al. (1963) found that steer meat was more tender than bull meat in a comparison of the eating quality of male twin cattle.

Breed

Species is the most general factor affecting tenderness mainly due to the size of the animal. Texture may also be implicated in breed differences, within a species, in tenderness. Even within a breed, however, tenderness is heritable to an extent of over sixty percent, indicating that texture is not the sole determinant of tenderness (Lawrie, 2006). Thus, selection is one of the most effective methods of making permanent improvements in the tenderness of fresh meat.

The relatively greater tenderness of the meat from Aberdeen Angus cattle can be partly explained by their small size. However, in a study by Jacobson et al. (1962) it became

apparent that other factors are involved since dwarf beef was judged less tender than beef from normal-sized animals. Peacock et al. (1982) showed that the introduction of the Brahman breed decreased beef tenderness. Though no differences between breeds has been found in the content of connective tissues, other factors such as the chemical nature of collagen could be implicated in creating differences in the tenderness of their meat (Lawrie, 2006).

Postmortem aging

Postmortem aging is defined as the storing of fresh beef at refrigerated temperatures to allow the natural enzymatic and biochemical processes that result in improved tenderness (National Cattlemen's Beef Association, 2009). Smith et al. (1978) found that tenderization due to postmortem aging was maximized 8 to 11 days postmortem and would improve tenderness, flavor, and palatability of U.S. Choice beef carcasses. Gruber et al. (2006) suggests that muscle-to-muscle tenderness differences depend on quality grade and aging time; therefore, postmortem aging should be managed with respect to individual muscle and USDA quality grade.

During the first 24 hours postmortem, research has shown that there is very little proteolytic degradation of cytoskeletal proteins. Proteolytic degradation of muscle proteins is also minimal up to the third day postmortem (Taylor et al., 1995). Taylor et al. (1995) found that postmortem tenderization involves a complex interplay among at least three interacting events. They are: an increased rigidity or strengthening followed by a weakening of the actin/myosin interaction, disruption and weakening of the connections between thin filaments in the I-band and the Z-disk, and degradation of the costameres and intermyofibril linkages. Wheeler and Koohmaraie (1994) found that the largest changes in tenderness occur

during the first three days postmortem when there is little proteolytic degradation. This explanation leaves a few unanswered questions about what is changing tenderness in the first 72 hours postmortem, however.

Temperature and pH

There can be considerable difference in tenderness caused by post-slaughter circumstances, the most important being post-mortem glycolysis. The rate and extent of post-mortem glycolysis have an effect on tenderness. The rate of pH fall post-mortem is inversely related to tenderness of the meat, indicating that there is a direct relationship between the time elapsing before rigor mortis and tenderness (Lawrie, 2006). Other post-mortem factors include length of time and temperature of storage after slaughter, and methods of trimming and cutting (Weir, 1960).

It has been determined that the degree of shortening during the onset of rigor mortis in muscle is a direct function of temperature down to about 15°C (Lawrie, 2006). Cold shortening is what ensues when the muscle is chilled below 15°C before the onset of rigor mortis (Hedrick et al., 1994). When meat is held in cold storage after slaughter, tenderness decreases during the first 24 hours while rigor mortis sets in, and then increases gradually (Weir, 1960). Rigor mortis is brought about by the disappearance of ATP from the post-mortem muscle. The consequence of this happening is cross bridging of the heads of the myosin with the g-actin monomers (Lawrie, 2006).

Busch et al. (1967) determined that steaks held for two days at 16°C were more tender than steaks held for 13 days at 2°C. This study is the basis for why packers now cold chill the carcasses for 24 hours after slaughter and before collecting carcass data.

Electrical Stimulation

Use of high-voltage electrical stimulation increases the tenderness of beef longissimus steaks. Packers in the United States have used it since the 1970's with no reports of concomitant beef quality problems (Roeber et al., 2000). An effect on tenderness from electrical stimulation is related to the immediate and more rapid decline in pH. The rapid lowering of pH in association with high carcass temperatures increases the free activity of β -glucuronidase and cathepsin C and thereby enhances autolytic proteolysis, thus increasing tenderness (Schroeder et al., 1982). In a study done by Roeber et al. (2000) it was indicated that beef became more acceptable in tenderness with the use of electrical stimulation. This same study found that electrical stimulation generated carcasses with more youthful lean maturity scores and more desirable lean color. The significant increase in flavor in the electrically stimulated beef samples may have resulted from more complete degradation of ATP to hypoxanthine (Lawrie, 2006).

There are three additional factors that describe how electrical stimulation tenderizes meat: 1) cold shortening prevention through acceleration of glycolysis and rigor onset before temperatures reach the cold shortening range; 2) accelerated proteolytic activity through enhanced calcium release; and 3) physical disruption of fiber structure through extreme muscle contractions (Hedrick et al., 1994).

Electrical stimulation shortening of the sarcomere is brief because when the current stops, the ATP levels are still relatively high and the temperature is a small amount lower than its in vivo temperature. The high ATP levels allow the sarcotubular system to recapture Ca^{++} ions, thus suppressing ATPase activity while the ATP level is sufficient for muscular relaxation and the restoration of resting sarcomere length (Lawrie, 2006). The membrane of

the sarcoplasmic reticulum is altered by electrical stimulation and the calcium-binding protein, calsequestrin, becomes more exposed (Lawrie, 2006). From these findings, Lawrie (2006) felt that this feature might possibly enhance the capability of the system to retain Ca^{++} ions.

A study by Wheeler et al. (1990) indicates that electrical stimulation reduced the length of postmortem aging needed to achieve a given level of tenderness.

Marbling

For many years, researchers have tried to determine whether marbling and tenderness were related. Carpenter (1974) concluded that practically all of the organoleptic attributes of beef are positively related to intramuscular fat content, but that less than 15 percent of the total variation in beef palatability is associated with differences in marbling (Tatum et al., 1982). Tatum et al. (1982) found that each of the palatability traits was positively related to marbling. In a study by Killinger et al. (2004) steaks of similar tenderness, but different levels of marbling were evaluated and high-marbled steaks were found to be more desirable in flavor and overall acceptability by consumers. However, not all consumers were willing to pay more for a highly marbled steak (Killinger et al., 2004).

Tatum et al. (1982) researched fat thickness as well as marbling effects on cooked beef palatability and found that when combined effects of marbling and fat thickness were examined, marbling had the greatest effect on palatability.

Cooking

Cooking may or may not cause an increase or decrease in tenderness. It depends on a variety of factors including the temperature to which the meat is raised, the time of heating,

and the particular muscle being cooked (Lawrie, 2006). During cooking, two general changes occur: the muscle fibers become tougher, and the connective tissue becomes more tender (Weir, 1960). In general, cooking makes connective tissue more tender by converting collagen to gelatin, but it also coagulates and tends to toughen the proteins of the myofibril and both of these effects depend on time and temperature of cooking (Lawrie, 2006). For muscles or cuts containing only small amounts of connective tissue, such as the ribeye, cooking methods involving dry heat for a short amount of time are used to minimize the toughening effect on the muscle fibers (Weir, 1960).

Appearance

The color of meat, both fresh and cooked, is very important to palatability. Consumers desire a fresh meat product that is bright cherry red, with creamy white fat and a cooked meat product that is brown in exterior color and pink to uniform gray in interior color (Lawrie, 2006). Consumers associate a bright cherry red as the normal color of fresh beef. The consumer perceives a dark red color in beef as a product that was improperly handled, lacked proper refrigeration, stored for excessive lengths of time, or that came from a stressed animal (Hedrick et al., 1994).

Myoglobin

Myoglobin is the pigment that gives meat its color. The color of cooked, uncured lean meat depends largely upon the nature and amount of myoglobin derivatives and decomposition products that are present. Species, age, sex, muscle, nutrition and physical activity all can have an effect on myoglobin quantity.

The color intensity of cooked fresh meat reflects the amount of myoglobin present in the raw lean muscle tissue. Thus, cooked meat from older animals usually is darker than

cooked meat from younger animals, and cooked meat from active animals is darker than that from less active animals due to the oxygen demand on the muscles (Weir, 1960). Most of the striking differences in the color of meat surfaces arise from the chemical state of the myoglobin molecules (Lawrie, 2006). To obtain the desirable red color of fresh meat, molecular oxygen reacts with the reduced iron of myoglobin. Deoxymyoglobin (purple pigment) occurs when iron in uncut meat is in the reduced form and has only water to react with because of normal enzyme activity, which uses all of the oxygen. Oxymyoglobin (red pigment) occurs when the freshly cut meat comes in contact with air. Metmyoglobin (brown pigment) is the oxidized form, which is when the iron ion is changed from the ferrous to ferric state (J. Sebranek, Iowa State University, Ames, IA, personal communication).

Cooked meat

The final color of cooked meat depends upon the pigment changes that take place during cooking. A brown color is desirable for cooked meat. The type, length of time, and temperature of cooking determines these changes. The temperature at which the meat is cooked affects the color. Beef cooked to an internal temperature of 60°C has a bright red interior; internal temperatures of 60-70°C provide a pink interior; and at an internal temperature of 70-80°C or higher a grayish brown interior results (Weir, 1960; Lawrie, 2006).

Flavor

Flavor is a complex sensation that involves odor, taste, texture, temperature and pH. Of these, odor is the most important. The response to odor involves chemical reactions between the molecules concerned and the nerve endings in the taste cells (Lawrie, 2006).

When odor effect is reduced or removed, meat flavors are extremely difficult to distinguish. The true meaty flavor develops during cooking and is thought to arise from the muscle fiber protein (Weir, 1960).

Flavor of meat is subject to variability in both intrinsic and extrinsic factors. Intrinsically, flavor may vary due to species, breed, sex, and age (Lawrie, 2006). Increasing animal age is associated with increased flavor intensity. It tends to increase up to 18 months of age and then plateau (Lawrie, 2006). Extrinsically, flavor may vary due to diet of the animal and processing of the meat.

Off-flavor can develop in meats. These can occur due to storage, microorganisms, diets, or from oxidation of lipids during cooking (Lawrie, 2006).

Diet

The diet of an animal sometimes causes an off flavor in the meat product. Lawrie (2006) indicates that forage-fed beef may have a 'grassy' flavor, making it less palatable, due to its high content of polyunsaturated fatty acids. Another example would be animals grazing on pastures containing weeds like peppergrass and ragweed. They are unable to excrete indole and skatole derived from tryptophan, which causes a taint in the meat (Lawrie, 2006). Flavor is not the result of a single compound and data varies significantly as to which compounds contribute to the flavor of meat. Fat flavor is affected by the diet of the animal. Excessive amounts of fish meal in the diet may cause a fishy flavor in the fat (Weir, 1960). Feed additives such as monensin and functional oils have not been found to change the flavor of the meat.

Rancidity

Fat may become rancid during storage and develop a fishy, oily, cheesy, or tallow flavor (Weir, 1960). Fat influences meat flavor by lipid oxidation of unsaturated fatty acids (Lawrie, 2006). Any process that damages the muscle membranes, such as chopping or emulsification, speeds up rancidity. However, rancidity can be slowed by the addition of antioxidants (Lawrie, 2006). Rancid meat has a sweet aroma and flavor, which has been attributed to increased amount of cis-6- γ -dodecenolactone according to Park and Murray, (1975) and the oily aroma is from increased levels on trans, trans-2,4-decadienal (Lawrie, 2006).

The warmed-over flavor of meat that occurs when meat is stored after cooking is also due to rancidity. It is an oxidative off-flavor; however, there is a series of complex chemical reactions that cause the deterioration of meat flavor contributing to the loss of desirable meat flavor (Lawrie, 2006).

pH

pH is the one major biochemical variable which affects the flavor of meat. In general, the higher the pH, the lower the flavor intensity, according to taste panelists (Lawrie, 2006). When meat is held for a set amount of time after ultimate pH has been reached, it is said to be “aged.” During this aging period the meat becomes more tender, however, the flavor is also altered. This alteration in flavor is due to changes in the free fatty acids during the aging period (Lawrie, 2006).

Sensory panel

While the chemical and physical methods of meat analysis are great guides to the quality of the meat, it is necessary to rely on human judgments to assess juiciness, tenderness, flavor and other palatability characteristics of the meat. Sensory tests are utilized to determine discrimination or preference. These tests can be done by a laboratory trained panel or a consumer survey (Brady, 1957). The use of a group of trained panelists is designed to determine differences in treatments and the magnitude of the differences of preference. The use of a consumer panel is designed to indicate a preference and/or the degree of preference for the samples being evaluated (Weir, 1960).

Training

Since individuals vary in taste preference and sensitivity, training is needed before the evaluation of meat samples in a laboratory trained sensory panel. Throughout the training, if it becomes apparent that a panelist is either too sensitive or not sensitive enough in palatability, they can be removed. This eliminates variability within the panel (K. Hanson, Iowa State University, Ames, IA, personal communication). The training period also assists panelists in learning how to best describe their taste impressions and to detect differences, which are normally ignored (Weir, 1960). The length of the training period is determined from the reproducibility of the panelists in scoring (K. Hanson, Iowa State University, Ames, IA, personal communication).

Evaluation

For evaluation of the meat samples, each panelist is given a one inch cube of meat, which was cooked on a grill heated to 350° to an internal temperature of 70°C. It is then distributed to them in a covered cup that is labeled with a blinding code. Panelists are placed

in a booth with an evaluation screen. All evaluations are done under red lights so the color of the meat does not influence the panelist's scores on juiciness, tenderness or flavor (K. Hanson, Iowa State University, Ames, IA, personal communication).

Compusense sensory software is utilized to record the scores from each of the panelists on juiciness, tenderness, flavor and off-flavor. Compusense software allows the researcher to input the palatability characteristics needing evaluation, and then displays the palatability characteristics on the computer screen for the panelists to evaluate and make comments. All panelists' scores are compiled and are ready for statistical evaluation (K. Hanson, Iowa State University, Ames, IA, personal communication).

Animal performance

Cattle feedlot producers utilize ionophores, such as monensin, to improve feed conversion. Much research has been done on the effectiveness of monensin in feedlot diets (Donoho, 1984; Goodrich et al., 1984; Potter et al., 1984; Schelling, 1984). Animal performance has improved with the incorporation of both ionophores in the diet and the usage of implants (Goodrich et al., 1984).

Functional oils

Functional oils are defined as those oils that have activities beyond their energy value. They are natural products that have been shown to have both antibacterial and antiprotozoan activity. It is important to note that functional oils are not the same as essential oils, as they are not essences like the ones used in perfumes and spices. A commercial product, "Essential™," utilizes functional oils as opposed to essential oils in order to minimize the risk of an off-flavor that may be unpalatable to the cattle. Essential™ is composed of a mix

of cashew nut shell liquid and castor oil (J. Torrent, Oligo Basics, Excelsior, MN, personal communication).

Functional oils can interact with microbial cell membranes and inhibit the growth of some gram-positive and gram-negative bacteria. The addition of plant extracts to the rumen inhibits deamination and methanogenesis, which results in lower ammonia nitrogen, methane, and acetate, and in higher propionate and butyrate concentrations (Calsamiglia et al., 2007). According to Van Nevel et al. (1971), methane production decreased with the number of double bonds in the alkyl chain. Van Nevel et al. (1971) suggested this was due to anacardic acids exerting a direct toxic effect on methanogenic bacteria.

Castor oil

Castor oil, from *Ricinus communis*, is a functional oil that has been used since ancient times as a safe and reliable laxative. The active molecule in the oil is ricinoleic acid. Besides its laxative effects, ricinoleic acid has been shown to have antimicrobial and anti-inflammatory actions (J. Torrent, Oligo Basics, Excelsior, MN, personal communication). Ricinoleic acid functions as a divalent ionophore, meaning the elements can unite with two atoms (Torrent, 2007).

Ricinoleate does not affect Ca-Mg ATPase activity, thus it could have significant intestinal secretory activity due to this Ca²⁺ ionophore property. Ricinoleic acid can induce fluid and electrolyte accumulation as well as induce active secretion of anions. Ricinoleate causes the release of prostaglandin E, which may be responsible for increased cyclic AMP concentrations (Maenz and Forsyth, 1982).

The FDA and European Commission consider castor oil and ricinoleic acid food fats, thus it does not have any toxicities or residues (Torrent, 2007).

Cashew nut shell liquid

The shell of the cashew nut (*Anacardium occidentale*) contains alkylphenolic oil, internationally named “cashew nut shell liquid” (CNSL), which constitutes nearly 25% of the total weight of the nut. This oil is composed of anacardic acid (3-*n*-pentadecylsalicylic acid), and smaller amounts of cardanol (3-*n*-pentadecylphenol), cardol (5-*n*-pentadecylresorcinol), the long aliphatic side-chain being saturated, mono-olefinic, diolefinic, and tri-olefinic with an average value of two double bonds per molecule (Amorati et al., 2001). Cashew nut shell liquid has many attractive biologic activities in the areas of molluscicidal activity (Kubo et al., 1986), anti-tumor activity (Itokawa et al., 1989), antimicrobial activity (Kubo et al., 2003), inhibition of α -glucosidase, invertase and aldose reductase (Toyomizu et al., 1993), inhibition of tyrosinase (Kubo et al., 1994), uncoupling effects on liver mitochondria (Toyomizu et al., 2000), antioxidant activity (Trevisan et al., 2005), and xanthine oxidase inhibition (Masuoka and Kubo, 2004). The antimicrobial action is from anacardic acid and cardol. The anti-inflammatory and antioxidant action are from cardanol (Torrent, 2007).

Studies by Kubo et al. (2003) and Muroi et al. (2004) showed anacardic acid had bactericidal activity against *Staphylococcus aureus* strains and the bactericidal action of methicillin against these strains was dramatically enhanced through combination with anacardic acid. The activity of anacardic acid comes, in part, from its ability to inhibit respiratory chain enzyme activity (Kubo et al., 2003). Anacardic acid was also found to have antibacterial compounds that inhibit urease in a study by Kubo et al. (1999). This property may be a good source of antiulcer agents, since it will come in contact with the lining of the stomach directly (Kubo et al., 1999).

A study by Toyomizu et al. (2000) suggests that the alkyl side chain, as well as the carboxyl group of anacardic acid may play an important role in assisting uncoupling activity of anacardic acids in liver mitochondria. Uncoupling agents dissipate the proton gradient, which uncouples electron transport from ATP synthesis in mitochondria. The uncoupling by fatty acids interferes with mitochondrial ATP synthase activity and results in an increase in mitochondrial state four respirations with a concomitant decrease in the ADP/O ratio. Cardanols were not found to have a profound uncoupling effect.

Cashew nut shell liquid contains the same active compounds that are present in the nut and apple of the cashew nut, thus it is safe for human consumption and will not leave any residues or toxicities (Torrent, 2007).

Worldwide cashew nut production is nearly 500,000 tons per year, so CNSL is available in large amounts (Amorati, 2001). Anacardic acids are rapidly accumulated in the shell during the early part of the growth of the cashew nut and may play an important role in the protection of the kernel as well as affecting the fruitfulness of the insect population living on the tree (Nagabhushana et al., 1995). Amorati et al. (2001) found that cardanol represents a renewable, low-cost, and convenient alternative source of a number of products having good antioxidant properties. “Essential™” utilizes CNSL in hopes that it will increase the antimicrobial activity of castor oil, so that castor oil can be used orally (J. Torrent, Oligo Basics, Excelsior, MN, personal communication). Anacardic acid and cardol both function as a monovalent ionophore, the same as monensin.

Monensin

Monensin is an ionophore that was approved for use in feedlot diets in 1975 (Goodrich et al., 1984; Schelling, 1984). Monensin is a feed additive that is known for its

ability to increase feed efficiency by decreasing feed consumption and not affecting rate of gain. The reduced feed intake occurs because monensin spares dietary protein from ruminal degradation. Other effects monensin has on feedlot cattle include improvement of dry matter digestibility while reducing methane losses, reduction of lactic acid production and the likelihood of feedlot bloat, and reduction of heat production as well as aiding in control of coccidiosis. The feeding of monensin results in increased ruminal propionate concentrations and reduced ruminal acetate concentration. Methane production is also reduced (Goodrich et al., 1984).

Lactic acidosis results with an abrupt change in diet or when cattle go off feed due to stress, then gorge on feed. This results in an accumulation of lactic acid in rumen fluid and blood, which produces clinical signs of acidosis. Monensin's influence on rumen microorganisms appears to make it a possible preventative of lactic acidosis. It inhibits most lactate-producing rumen bacteria including the two major lactate producers, *Streptococcus bovis* and *Lactobacillus* species. Therefore, utilizing monensin results in reduced lactate production, but does not reduce lactate utilization via propionate formation. Monensin increases dietary net energy for maintenance values more than it increases net energy for gain values, thus reducing dry matter requirements for maintenance (Goodrich et al., 1984).

Monensin is a compound produced by *Streptomyces cinnamonensis* and belongs to the chemical class termed polyethers. Therefore, if fed too high of concentrations, cattle will show signs of mild monensin intoxication and mortality could ensue if not fixed in a timely manner. It is commonly observed, however, that cattle consume very little feed for several days after monensin overdose (Potter et al., 1984). Monensin that is administered orally is absorbed, extensively metabolized, excreted in the bile, and eliminated in the feces. It does

not accumulate in the tissues, thus does not leave any residues. Environmental studies indicate that monensin is biodegradable in manure and soil (Donoho, 1984). It has been established that there are no detrimental effects to reproduction from feeding monensin (Potter et al., 1984).

The basic mode of action of monensin is to modify the movement of ions across biological membranes, thus the name ionophore, which means “ion bearer.” However, it is the system modes of action that implement the animal performance response that is observed when monensin is fed to animals and there are seven accepted or probable system modes of action of monensin (Schelling, 1984). Responses of cattle to monensin and implants are additive (Goodrich et al., 1984).

Implants

For the past 50 years beef producers have utilized growth-promoting implants to improve growth rates by 30% and feed efficiency by 15%. Many studies have shown implants to increase hot carcass weight, loin muscle area and dressing percent as well (Bruns et al., 2005; Barham et al., 2003; Smith et al., 2007). Anabolic implants enhance animal performance and carcass protein accretion through an increase in longissimus muscle area (Smith et al., 2007). In 1991 the option of using a single implant that contained both an estrogen and an androgen (trenbolone acetate) was made available to producers (Bruns et al., 2005). When trenbolone acetate and estrogenic implants are combined, they often have synergistic effects on growth (Barham et al., 2003; Bruns et al., 2005). Results from a study conducted by Barham et al. (2003) indicate that using a moderate implant program in *Bos indicus*-influenced cattle has no detrimental effects on beef tenderness and consumer acceptability. Results from a study conducted by Bruns et al. (2005) showed that a combined

implant of estradiol-trenbolone acetate could affect carcass traits and the growth rate of carcass protein and fat depending on the point of administration in the feeding phase of production. These results suggest that using a combined implant early in the finishing phase could have adverse effects on the development of marbling (Bruns et al., 2005). A study by Smith et al. (2007) shows that anabolic implants have no direct effects on intramuscular lipid deposition.

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CHAPTER 2. THE EFFECTS OF FUNCTIONAL OILS ON SENSORY ATTRIBUTES OF BEEF RIB-EYE STEAKS

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Abstract

The effect of feeding Essential™, a product of functional oils, on the meat quality of finishing cattle was observed in two one-year trials. Year one included 120 steer calves (average initial weight 322kg). Year two included 120 steer calves (average initial weight 344kg). In each year five treatments were utilized with four replications and six animals in each replication. Treatments were control (C), monensin (223 mg/hd/d; M), monensin (223 mg/hd/d) + Essential™ (250 mg/kg DMI; ME), Essential™ Low (250 mg/kg DMI; EL), and Essential™ High (500 mg/kg DMI; EH). In year one all steers were fed the same diet (0.29 Mcal of NEg/kg DM, 0.41 Mcal of NEm/kg DM) on an ad libitum basis, treatments M and EL for 172 days and treatments C, ME, and EH for 179 days. Steers were harvested at an average weight of 617kg. In year two all steers were fed the same diet (0.29 Mcal of NEg/kg DM, 0.41 Mcal of NEm/kg DM) on an ad libitum basis, treatments M and ME for 154 days and treatments C, EL, and EH for 161 days. Steers were harvested at an average weight of 596kg. At the conclusion of the feeding trial, cattle were harvested and a ribeye steak was removed from each carcass for sensory evaluation. In year one, hot carcass weight showed no evidence of a difference among treatments. Quality grades (1=low standard, 7=low choice, 12=high prime) for C, ME and EL treatments were, 6.46, 6.50, and 6.57, respectively, and were higher ($P<0.05$) than the M treatment and lower ($P<0.05$) than the EH treatment, 6.25, and 7.06, respectively. There was no evidence of differences in ribeye area, backfat,

KPH, or yield grade among treatments in the first year. In year two, yield grade was better ($P<0.05$) for ME when compared to EL, but no evidence of other differences were found. There was no evidence of differences in hot carcass weight, quality grade, ribeye area, backfat, or KPH between treatments in the second year. Sensory panel evaluations determined that juiciness, tenderness, and beef flavor were unaffected by treatments. There was no off flavor found for treatments C and EL. A small off flavor was found in treatments M, ME, and EH; however, there was no evidence of a difference among treatments for off flavor. Results of this study indicate that steer calves provided functional oils in their diet produce carcasses with acceptable yield and quality grades and that the eating qualities of the meat will be equally as good as cattle provided monensin or no monensin in their diet.

Keywords: functional oils, meat quality, quality grades, ionophore

Introduction

Functional oils, natural products, have been introduced into the United States because they are thought to offer similar benefits as ionophores without the drawbacks of synthetic products, as well as antioxidant benefits. The antioxidant status of an animal influences both its health and meat quality characteristics. This study consisted of a commercial mixture of functional oils (Essential™, Oligo Basics USA LLC, Wilmington, DE), composed of cashew nut shell oil and castor oil, used alone and in combination with monensin to evaluate the effects on steers carcass performance and eating qualities when fed a high concentrate diet.

Consumers of beef today are looking for a natural product that is still highly palatable. With the European Union banning the use of antibiotic ionophores, scientists have

been evaluating other alternatives to reduce energy and protein losses in the rumen (Calsamiglia et al., 2007). A solution would be natural products that function similar to ionophores.

This experiment was designed to evaluate an alternative feed additive of natural origin for finishing cattle while maintaining carcass quality and meat quality. The objectives of this research were to determine the carcass qualities and eating qualities of ribeye steaks from cattle fed different feed additives during the finishing program. The overall objective was to provide consumers beef products produced by natural products.

Materials and Methods

Treatments

A two-year study was initiated in December 2007 at the Iowa State University Beef Nutrition Center in Ames, Iowa to evaluate the effects of functional oils fed as a growth promotant on the feedlot performance, carcass composition and the meat quality of beef carcasses. This paper will focus on the evaluation of meat quality. Crossbred steers were obtained from various sources in Iowa and Missouri.

In the first year, 120 calves were used. The calves arrived on December 5, 2007 and were processed on December 11, 2007. The processing included identification by ear tag, injection of Dectomax® and treatment with Cydectin® pour-on. On December 21, 2007, the calves were implanted with Component E-S®; blood was collected, and the calves were randomly allotted into 20 pens of six animals each. The calves' average weight for the start of the study was 322 kg.

A total of five treatments were established with each treatment having four replications. The first treatment (control group) consisted of 24 steers that were fed a diet

consisting of 82% concentrate containing whole shell corn, wet distiller's grain, protein, vitamin and mineral supplement, and 18% tall fescue hay. This diet was fed to all cattle on all treatments. The second treatment (M) consisted of 24 steers that were fed the control diet plus 223 mg/hd/d monensin. The third treatment (ME) consisted of 24 steers that were fed the control diet plus 223 mg/hd/d monensin and 250 mg/kg DMI Essential™. The fourth treatment (EL) consisted of 24 steers that were fed the control diet plus 250 mg/kg DMI Essential™. The fifth treatment (EH) consisted of 24 steers that were fed the control diet plus 500 mg/kg DMI Essential™.

The steers were re-implanted with Component TE-S® 137 days after the start of the trial, May 6, 2008.

In the second year, the protocol was similar to the first year except the diet was changed on December 9, 2008 to include modified distiller's grain in place of wet distiller's grain. The cattle arrived September 30, 2008 and were allotted to one of five treatments on October 7, 2008 with an average weight of 344 kg. The same five treatments as the first year were used with each treatment having four replications. The steers were re-implanted with Component TE-S® 84 days after the start of the trial, December 30, 2008.

The feedlot facilities were divided into 20 lots with concrete floors and a shelter at the north end. Steers were fed in fence-line concrete bunks on the north side of the lot and had access to automatic waterers. Feeding levels were determined daily prior to the morning feeding, based on the amount fed and eaten the previous day. Feed samples were collected once per week for dry matter determination.

The steers were weighed individually every twenty-eight days. When the average weight of the steers in each treatment reached 617 kg in the first trial and 596 kg in the

second trial, the cattle were harvested at a commercial packing plant (Tyson, Denison, IA). During processing, carcasses were subjected to electrical stimulation prior to chilling. Carcasses were allowed to chill for 24 hours prior to the collection of backfat and ribeye area measurements, and quality and yield grades were provided by the USDA Meat Grading service. Ribeye steaks (~5 cm) were removed from the left side of each carcass at the twelfth rib, were aged for 24 hours, and used for subsequent sensory evaluations.

Sensory Panel Evaluations

A subjective measurement evaluation process was conducted for meat quality determination. Subjective measurements were completed by a panel of volunteers. Steaks were evaluated by a nine member sensory evaluation panel after they were trained to eliminate variability within the panel and also trained on how to best describe their taste impressions and to detect differences (Weir, 1960; Kathy Hanson, Iowa State University, Ames, IA, personal communication). Testing was conducted by tasting steaks from 60 animals per year and recording observations utilizing Compusense software. The score sheet (Appendix) was based on an unstructured line scale where they marked a place on the line from not juicy to juicy, not tender to tender, no beef flavor to intense beef flavor, and no off flavor to intense off flavor. The line was 15cm long; it was measured where the mark was placed and the score corresponded to the mark on the line. Meat quality characteristics evaluated were juiciness, tenderness, beef flavor, and off flavor. Panelists were seated in partitioned booths under red fluorescent lights to mask differences due to degree of doneness. Panelists were provided water and unsalted crackers to cleanse their palates between samples.

Sample preparation and guidelines for cooking procedures were done according to “Research Guidelines for Cookery, Sensory Evaluation and Instrumental Tenderness Measurements of Fresh Meat” (AMSA, 1995). Steaks were chosen based on the calves starting weight. Steaks from the lightest, middle, and heaviest steers were chosen from each pen, for 120 steaks over the two-year trial.

Steaks were cooked on a George Foreman® grill preheated to 350 degrees. Steaks were trimmed to uniform thickness and a temperature probe was inserted into the middle part of the steak. When the steaks reached an internal temperature of 70 degrees, the probe was inserted into two different places to ensure uniform cooking, and then removed from grill. The steak was cut into one-inch cubes and placed in a covered Styrofoam cup, labeled with a blinding code, for distribution to the panelists. Steaks were distributed to the panelists individually through a small door in their booth. Each panelist gave one score for each steak on a sensory evaluation score sheet. Treatment averages of the steaks were used for a one way analysis of variance.

Statistical Analysis

In this experiment the experimental unit was pen of cattle consisting of six steers. There were five treatment combinations with four repetitions in each year. The analysis took the form of a one-way analysis of variance with four degrees of freedom for treatments. The data were analyzed using the proc mixed procedure of SAS (Littell et al., 2002). Contrasts were performed to test for differences among all treatments.

Results and Discussion

The least square mean values for hot carcass weight (HCW), backfat (BF), ribeye area (REA), kidney, pelvic and heart fat (KPH), yield grade (YG), and quality grade (QG) for

both years are presented in Table 1. Hot carcass weight showed no evidence of a difference among treatments. Ribeye area for the EH treatment was 34.54cm² and was higher (P<0.05) than the M treatment, but not different from the other treatments. There was no evidence of differences in BF, KPH, YG, or QG among treatments in the first year. This is consistent with findings reported by Potter et al. (1976) who found that monensin had no effect on carcass characteristics.

Table 1. Cattle feedlot carcass data

	Diets					
	C ¹	M	ME	EL	EH	SEM
Hot carcass wt, kg	371.6	366.6	373.1	366.0	371.7	13.75
Backfat, cm	1.35	1.24	1.30	1.35	1.35	0.04
Ribeye area, cm ²	33.96 ^{ab}	33.02 ^a	33.38 ^{ab}	33.32 ^{ab}	34.54 ^b	0.27
Kidney, pelvic heart fat, %	2.49	2.58	2.35	2.55	2.55	0.11
Yield grade	2.73	2.72	2.50	2.75	2.67	0.14
Quality grade ²	6.77	6.86	6.93	6.87	7.20	0.32
Low Choice or higher, %	69	65	69	72	75	

^{abc}Means within rows with different superscripts differ (P<0.05).

¹C=Control, M=monensin (223mg/hd/d), ME=monensin (223mg/hd/d) + EssentialTM (250mg/kg DMI), EL=EssentialTM Low (250mg/kg DMI), EH=EssentialTM High (500mg/kg DMI).

²High Choice=9, Choice=8, Low Choice=7, High Select=6.

When the two trials were combined, the sensory panel found no evidence of differences among treatments for juiciness, tenderness, or beef flavor (P<0.05; Table 2). According to Ouali (1990), tenderness and juiciness are typically related because of the

degradation of muscle and a reduction in myofibrillar strength, which might facilitate the release of juices during chewing. Diets C and EL showed no evidence of a difference from zero when the main effects were tested against zero for off flavor. However, there is no evidence of a difference among diets for off flavor ($P < 0.05$). The supplements evaluated in this study did not alter the sensory properties of the meat. Partida et al. (2007) found similar results in a study that fed palm oil to bulls.

Table 2. Least square means for sensory panel evaluation of ribeye steaks

	Diets					SEM
	C ¹	M	ME	EL	EH	
Juiciness	8.97	9.05	9.55	9.42	9.61	0.31
Tenderness	7.19	6.93	8.04	6.87	7.10	0.42
Beef flavor	6.97	6.70	6.76	6.92	6.57	0.23
Off flavor	0.13	0.35	0.29	0.13	0.39	0.12

¹C=Control, M=monensin (223mg/hd/d), ME=monensin (223mg/hd/d) + EssentialTM (250mg/kg DMI), EL=EssentialTM Low (250mg/kg DMI), EH=EssentialTM High (500mg/kg DMI).

Implications

The utilization of EssentialTM as a natural feed additive for cattle feedlot diets shows when fed at levels of 250 or 500mg/kg DMI, eating qualities are similar to diets consisting of no feed additives and no off flavor is detected. Results suggest that cattle provided functional oils in their diet at these levels perform equally as well in carcass composition and

sensory evaluation as cattle provided a more traditional ionophore such as monensin or no ionophores in their diet.

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Appendix. Sensory Evaluation of Rib-eye Steak

Panelist Code _____

Date _____

JUICINESS

Not juicy

Juicy

TENDERNESS

Not tender

Tender

BEEF FLAVOR

None

Intense

OFF-FLAVOR _____

None

Intense

Comments:

CHAPTER 3. GENERAL CONCLUSIONS

In this study the effect of utilizing functional oils as a feed additive in feedlot cattle diets generally provided similar results among treatments. Research showed that diet did not affect palatability characteristics such as juiciness, tenderness, beef flavor, or off flavor of ribeye steaks.

In year one, differences ($P < 0.05$) among treatments existed for quality grade; however in all diets, more than half the quality grades were Low Choice or higher. In year two, differences ($P < 0.05$) among treatments existed for yield grade; however, all yield grades were within the yield grade 2 category.

Thus, the utilization of functional oils as a natural feed additive in feedlot cattle diets did not adversely affect the eating qualities of beef.

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