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Angelo State University
Management, Instruction, and Research (MIR) Center

The Angelo State University Management, Instruction, and Research Center is located on the northern shore of O.C. Fisher Lake in San Angelo, Texas. The Center is situated between the Edwards Plateau and Rolling Plains regions of Texas. Elevation of the area is approximately 1,950 ft above sea level with an average annual precipitation of 21 inches. Topography of the region is nearly flat with level clay loam soils with occasional shallow ridges and small drainages. The 235-day average growing season supports mainly warm season grasses, forbs and shrubs, including a mixture of Edwards Plateau and Rolling Plains vegetation.

The Management, Instruction, and Research (MIR) Center serves three primary objectives. The first objective is to conduct research to improve animal production, agronomic production, food technology, and range and wildlife management. These include studies related to improving the reproductive and nutritional efficiency of sheep, cattle, and goats in conjunction with projects designed to improve range and wildlife management practices. Some research projects are very basic in nature and designed to better understand mechanisms controlling animal and plant production. Others are applied studies with immediate implications for management.

The second objective is to serve as a demonstration site for Agricultural industry. This objective is accomplished by managing rangelands for livestock, wildlife, and food production. The development of sustainable, economically efficient management systems is a primary a focus of the MIR Center. All experiments, investigations, and research projects sponsored through the Management, Instruction, and Research Center are open for review by the public. Seminars and field days are being conducted every year to provide to the citizens of West Texas the results of the projects being undertaken at the Center. Personnel at the Center are available to assist ranchers, farmers, and others in the region with management problems associated with their operations. Where appropriate, results of research and management demonstrations are published in area newspapers, magazines, and agricultural

journals. The Center's facilities are also utilized by various agricultural groups for meetings throughout the year which include a 4-H/FFA livestock judging contest, wool and mohair judging contest, land judging contest, wildlife contest, and a range and pasture evaluation contest.

The third objective of the MIR Center is to serve as a laboratory and outdoor classroom for the undergraduate and graduate programs in Agriculture. Laboratory classes are taught weekly at the MIR Center for Agriculture, Agronomy, Animal Science, Food Science, and Range Management courses. Undoubtedly, these "hands-on" experiences have been essential in shaping the knowledge of the department's 848 graduates since 1974.

The MIR Center is crucial for the Master of Science (M.S.) program in Animal Science. Since 1978, the department has produced 150 M.S. graduates. Several of those have continued their education at other universities by pursuing a Ph.D.

Mention of a trademark or a proprietary product does not constitute a recommendation of an endorsement of the product by Angelo State University nor does it imply its approval to the exclusion of other products that also may be suitable.

MIR Center Advisory Board

An advisory board was established for the MIR Center by the Board of Regents in November 1989 to advise the director of the MIR Center and the University administration with regard to the mission and the overall management and operation of the Center, to review and assess the programs and activities conducted by the Center, and to make recommendations to the Director of the MIR Center for improvements, modifications, and/or additions to the programs and activities conducted by the Center. The Director of the MIR Center serves as Chairman of the Advisory Board, which consists of the following members:

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San Angelo, Texas, Dean of the College of Sciences, Angelo State University.

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Dr. Gil R. Engdahl
Director of the Management, Instruction, and Research Center and Head of the Department of Agriculture. *Speciality: Animal Nutrition and Sheep and Goat Production.*

Dr. Kirk Braden
Research Scientist and Assistant Professor. *Speciality: Meat Science*

Dr. Mandy Carr
Research Scientist and Associate Professor. *Speciality: Food Technology and Meat Science.*

Dr. Gretchen Hilton
Former Research Scientist and Assistant Professor. *Speciality: Meat Science and Animal Production*

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Research Scientist and Associate Professor. *Speciality: Forage Crops.*

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Dr. Cody B. Scott
Research Scientist and Associate Professor. *Speciality: Grazing Management and Plant-Herbivore Interactions.*

Dr. Donald R. Shelby
Professor Emeritus. *Speciality: Animal Physiology and Genetics.*

Mr. Dennis W. Block
Research Technician.

Mr. M. Todd Schafer
Coordinator of Research.

Dr. E. James Hindman
President, Angelo State University.

Dr. Donald Coers
Vice President for Academic Affairs, Angelo State University.

Dr. Richard Beck
Associate Vice President for Academic Affairs, Angelo State University.

Dr. Grady Price-Blount
Dean of the College of Sciences, Angelo State University.

Dr. Carol B. Diminnie
Graduate School Dean, Angelo State University.

Adjunct Faculty

Dr. B. Frank Craddock
Adjunct Professor of Animal Science and Professor, Texas Agricultural Experiment Station, San Angelo, Texas. *Speciality: Sheep and Goats.*

Dr. Todd R. Callaway
Adjunct Professor of Animal Science and Research Scientists, Agricultural Research Service, USDA, College Station, Texas. *Speciality: Microbiology*

Dr. Christopher J. Lupton
Adjunct Professor of Animal Science and Professor, Texas Agricultural Experiment Station, San Angelo, Texas. *Speciality: Wool and Mohair Research.*

Dr. Rick Machen
Adjunct Professor of Animal Science and Professor, Texas Agricultural Experiment Station, Uvalde, Texas. *Speciality: Livestock Production.*

Dr. Allen McGinity
Adjunct Professor of Animal Science and Professor, Texas Agricultural Experiment Station, San Angelo, Texas. *Speciality: Brush Control, Poisonous Plants.*

Dr. William E. Pinchak
Adjunct Professor of Animal Science and Professor, Texas Agricultural Experiment Station, Vernon, Texas. *Speciality: Range Nutrition.*

Dr. Dale Rollins
Adjunct Professor of Animal Science and Wildlife Extension Specialist, Texas Agricultural Experiment Station, San Angelo, Texas. *Speciality: Wildlife Management.*

Dr. Charles A. Taylor Jr.
Adjunct Professor of Animal Science and Supervisor, Texas Agricultural Experiment Station, Sonora, Texas. *Speciality: Range Nutrition.*

Dr. Daniel F. Waldron
Adjunct Professor of Animal Science and Professor, Texas Agricultural Experiment Station, San Angelo, Texas. *Speciality: Animal Genetics.*

Dr. John W. Walker
Adjunct Professor of Animal Science and Director, Texas Agricultural Experiment Station, San Angelo, Texas. *Speciality: Ruminant Foraging Behavior.*

Dr. Travis Whitney
Adjunct Professor of Animal Science, Texas Agricultural Experiment Station, San Angelo, Texas. *Speciality: Ruminant Nutrition*

Authors

Haley Babb, Former Graduate Student

Mandy Carr, Associate Professor and Research Scientist

Blake Coates, Graduate Student

David L. Cocke, Professor of Chemical Engineering, Lamar University

Rob Cook, Former Graduate Student

Ross Copeland, Graduate Student

Matthew Dahlberg, Former Graduate Student

Curry Dawson, Former Graduate Student

Bobby Deeds, Former Graduate Student

Timothy Dietz, Former Graduate Student

Ned Dunbar, Former Graduate Student

Wayne Dunson, Former Graduate Student

Gil Engdahl, Head, Director of the MIR Center

Chad George, Graduate Student

Lauren Hahn, Former Graduate Student

Will Hartnett, Former Graduate Student

Gretchen Hilton, Former Assistant Professor

Ronald Horst, National Animal Diseases Center

John Kellermeier, Former Graduate Student

Tabitha Lloyd, Graduate Student

Brian May, Associate Professor and Research Scientist

Norberto Mendoza, Former Graduate Student

Paul Morkovsky, Applications Engineer, Kaselco

Alfredo Munoz, Graduate Student

Corey Owens, Graduate Student

Andrea Payan, Graduate Student

Jamin Phipps, Former Graduate Student

Rod Reed, Associate Professor and Research Scientist

Heather Rogers, Undergraduate Student

Mike Salisbury, Associate Professor and Research Scientist

Natalie Sato, Former Graduate Student

Todd Schafer, Coordinator of Research

Cody Scott, Associate Professor and Research Scientist

Joe Self, Former Graduate Student

Ned Strength, Professor of Biology

Charles Taylor, Adjunct Professor

Lacy Vinson, Former Graduate Student

Dustin Yates, Graduate Student

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PRECONDITIONING GOATS TO INCREASE CONSUMPTION OF REDBERRY JUNIPER ON PASTURE

Timothy H. Dietz, Cody B. Scott, Charles A. Taylor, Jr. and Corey Owens

INTRODUCTION

Redberry juniper (*Juniperus pinchotii*) cover continues to increase throughout the southwestern states, including Texas, Oklahoma, New Mexico, Arizona, and the country of Mexico (Ansley et al. 1995). Redberry juniper is a basal-sprouting, evergreen historically found on rocky outcrops and north-facing slopes where it was protected from intense grass fires (Ellis and Schuster 1968). During the past century, redberry juniper has encroached onto adjacent slopes and grasslands reducing the amount of available forage for grazing animals (Dye et al. 1995).

Various control methods have been implemented in order to manage redberry juniper including mechanical treatments (chaining, root plowing, grubbing), chemical treatments (spraying), and prescribed burning. One method that has not been fully explored is biological control; the use of a living organism to control an unwanted species. There is some preliminary evidence that suggests goat browsing will reduce the number of juniper seedlings thereby slowing the rate of juniper encroachment (Taylor 1992). Most livestock species avoid juniper because of monoterpeniods found in the plant that cause aversive postingestive feedback and the formation of conditioned food aversions (Riddle et al. 1996; Pritz et al. 1997). It appears that goats can adapt to the terpenoids in juniper if they are exposed to the plant slowly over several days (Bisson et al. 2001). Two studies confirmed this observation by feeding juniper to
increased intake daily until an apparent toxic threshold was reached. Thereafter, intake leveled off and remained high throughout the studies. Preliminary evidence also suggests that goats will continue to consume juniper on pasture after feeding juniper in pen situations (Ellis 2001). However, the pasture phase of the Ellis (2001) study was not replicated, and goats were only on pasture for 6 weeks.

This study compared juniper preference throughout the year for goats fed juniper in individual pens before release on pasture and for goats naïve to juniper.

METHODS

Forty female Boer-cross goats were randomly allocated to one of two treatments. Treatment 1 consisted of goats fed juniper for 14 days prior to initiation of the study, while Treatment 2 consisted of goats naïve to juniper. Goats were placed on juniper-infested pastures at the Texas Agricultural Experiment Station, Sonora, TX for 12 months with preference monitored twice monthly. Herbaceous forage availability was also monitored once monthly. Fresh water and a calcium/phosphorus mineral supplement with trace minerals was available *ad libitum* to all goats throughout the study.

Prior to release on pasture, 20 Boer-cross female goats (average weight 29.2 kg, 6 months old) (Treatment 1) were placed individually in pens and fed juniper

for 1 hour daily for 14 days at the Angelo State University Management, Instruction, and Research Center, San Angelo, TX. Juniper was harvested at the Texas Agricultural Experiment Station, Sonora, TX and leaves were stripped prior to feeding to the goats. Juniper was stored at 0^{o}C until feeding. The remaining 20 goats (Treatment 2) were fed alfalfa (2.0% BW) for 14 days.

Juniper was fed at the same time each day for one hour and refusals were weighed back to determine intake. Goats were allowed free-access to fresh water and a calcium/phosphorus mineral with trace elements throughout the pen-feeding phase of the study. All goats within this treatment also received alfalfa pellets in addition to juniper (2.0% BW) to meet daily maintenance requirements (NRC 1981).

After the 14-day preconditioning period, goats were transported to the Texas Agricultural Experiment Station, Sonora, TX and placed in pastures depending on treatment allocation. Ten goats were placed on one of four equally sized pastures with similar vegetation cover. Two pastures housed goats that were preconditioned to consume juniper and two pastures housed goats that were naïve to juniper. Pastures were stocked at a moderate stocking rate on a year-round basis.

To monitor forage preference, bite count surveys were conducted twice monthly by plant species for individual goats (Lehner 1987). All pastures were observed on a given day. Observations occurred in each pasture for 100 min in the morning and 100 min in the afternoon during peak feeding intervals. Bite count data was recorded by watching an individual goat for 10 min followed by watching a different goat in the same treatment until all goats were observed.

Canopy cover of all shrubs was measured at the initiation and cessation of the study. Eight 30 m transects were established in each pasture. Canopy cover by species was determined by measuring shrub foliage that intersects the transect line.

Forage availability per pasture was determined by clip samples taken initially and each month of the study. Ten 1/3 m^2 quadrats were clipped by species in each pasture. Samples were dried at 60º C for 48 hours and then weighed for dry matter weight.

Data were analyzed and differences between treatments and months were compared using repeated measures analysis of variance. Initial canopy cover and forage availability was compared among pastures and between treatments using analysis of variance. During the initial feeding of juniper, individual goats nested within treatments served as replications. During the pasture phase of the study, observations were nested by month and by pasture, with pastures serving as replications. Means were separated using least significant difference (LSD) with $P<0.05$. Linear regression analysis was used to determine any relationship between forage preference and forage availability and juniper preference. Data was analyzed using the statistical computer package JMP (SAS 1994).

RESULTS

Goats fed juniper during the preconditioning phase increased intake daily across the 14 days of feeding (Fig. 1). Goats were reluctant to consume juniper on day 2 through day 8. Intake increased on day 9 and 11 before declining on days 12 and 13.

Initial canopy cover was similar among pastures and treatments for juniper and liveoak, the two predominant shrubs (Table 1). Other shrubs (e.g., algerita, lotebush, persimmon) cover estimates were higher in the naïve pastures. Initial herbaceous vegetation differed among treatments (naïve pastures = 2,315.34 kg/ha, preconditioned pastures = 1,399.5 kg/ha of available forage).

Goats were released on pasture on April 8, 2005. Goats familiar with juniper (i.e., preconditioned) consumed more juniper than naive goats over the 12 months of the study (22.5% of total bites vs. 7.7% of total bites). The treatment by month interaction also differed (Fig. 2). Juniper preference for both familiar and naive goats varied by month, however, familiar goats consistently consumed more juniper than naive goats with the exception of the first and last months of the study. Naïve goats consumed primarily herbaceous forage (80% of total bites vs. 64% of total bites for preconditioned goats). Herbaceous and shrub preference varied by treatment and by month (treatment X day interaction differed; $P<0.05$) (Fig. 3 and Fig. 4). Naïve goats consumed more herbaceous forage than preconditioned goats with the exception of November. Other shrub intake varied by month with no consistency of one treatment selecting other shrubs over the other treatment.

Juniper preference was influenced by preference for other forage classes. The correlation coefficient (R^2) for juniper consumption (dependent variable) when compared to herbaceous preference (independent variable) was 0.36 for naïve goats and 0.5 for preconditioned goats. Juniper preference was not correlated to other shrub selection (R^2 =0.004 for naïve goats, 0.04 for preconditioned goats). When other shrub intake was used as the dependent variable and herbaceous preference was used as the independent variable the R^2 was 0.57 for naïve goats, but only 0.21 for preconditioned goats.

DISCUSSION

Prior to the initiation of this study, it was clear that goats would increase consumption of juniper when fed the plant at weaning in individual pens (Bisson et al. 2001; Ellis et al. 2005; Dunson et al. 2006). These trials relied on feeding juniper for 10 to 14 days and resulted in the same outcome. Goats were reluctant to consume juniper initially, however, goats would increase intake to the point of juniper accounting for up to 32% of the diet. In these studies, there was very little variation among individuals and intake typically increased daily until the end of the feeding trial. In the current study, some of the observations from the preconditioning phase of the study were the same; goats were reluctant to consume juniper initially, but increased intake over the 14 days of feeding. However, in the current study, intake fluctuated more daily and there was more variation among individual goats. Goats in the this study were older than goats used in previous studies (6 months vs. 4 months) which may have accounted for the variation in juniper consumption. Goats in this study

Table 1. Percent (%) canopy cover of the major shrub components. Each treatment consisted of two equal-sized pastures.

	Treatment		
Shrub Species	Preconditioned	Naïve	SEM
Juniper	20.3	19.6	4.9
Liveoak	11.7	8.0	5.8
Other Shrubs	3.2	8.6	1.6
Total	35.2	36.2	8.5

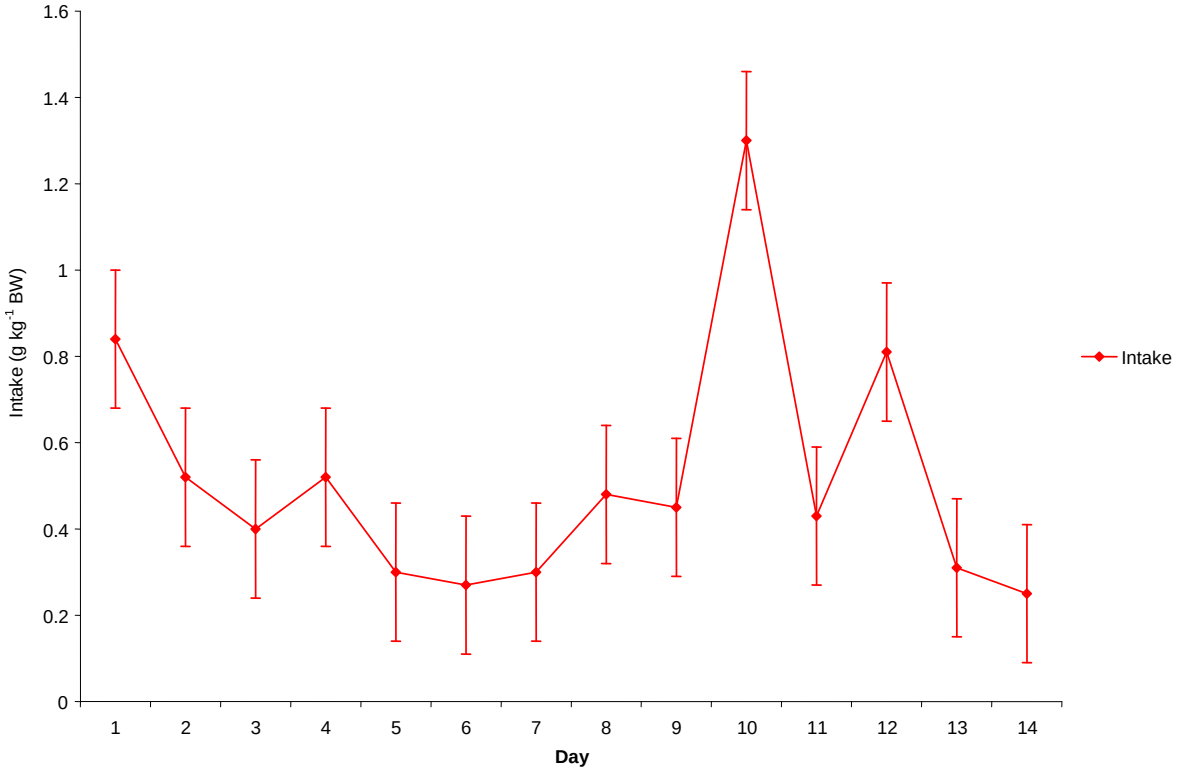

Figure 1. Intake (g kg^{-1}BW) of juniper for goats during 14 day preconditioning period. Goats were offered redberry juniper for 2 hours daily and intake was monitored daily. Alfalfa was fed at 2% BW to meet maintenance requirements.

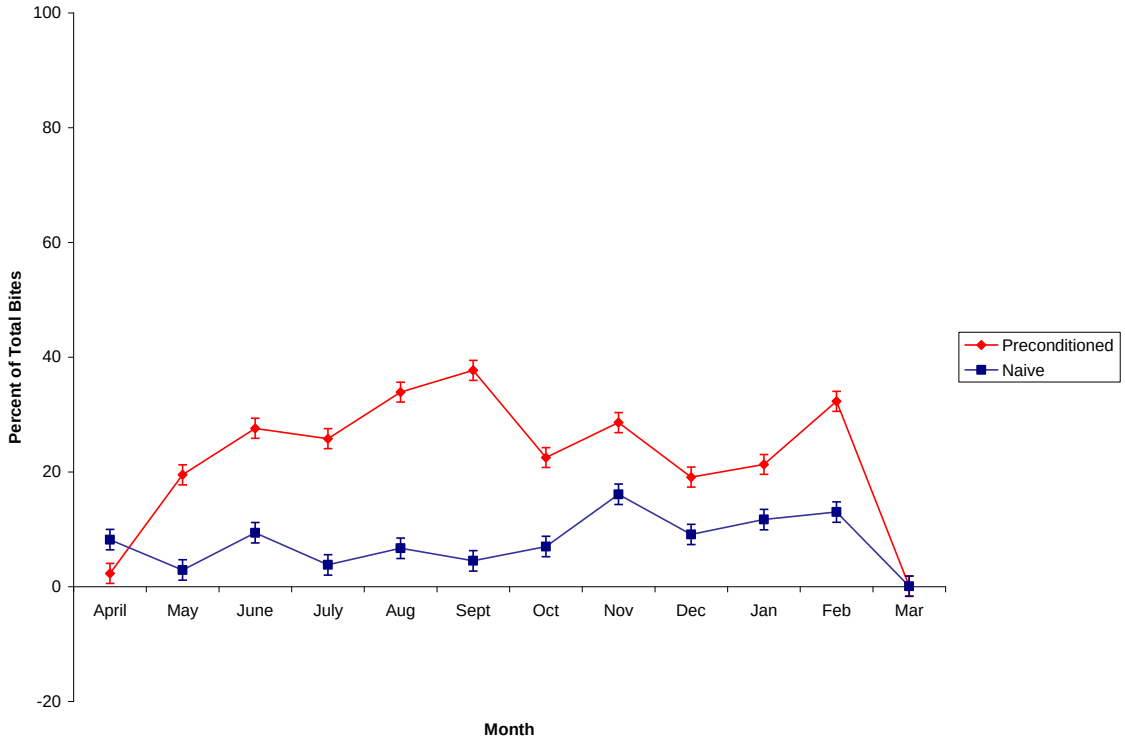

Figure 2. Preconditioned vs. naïve preference for juniper (percent of total bites) on pasture over 12 months of observations on pasture.

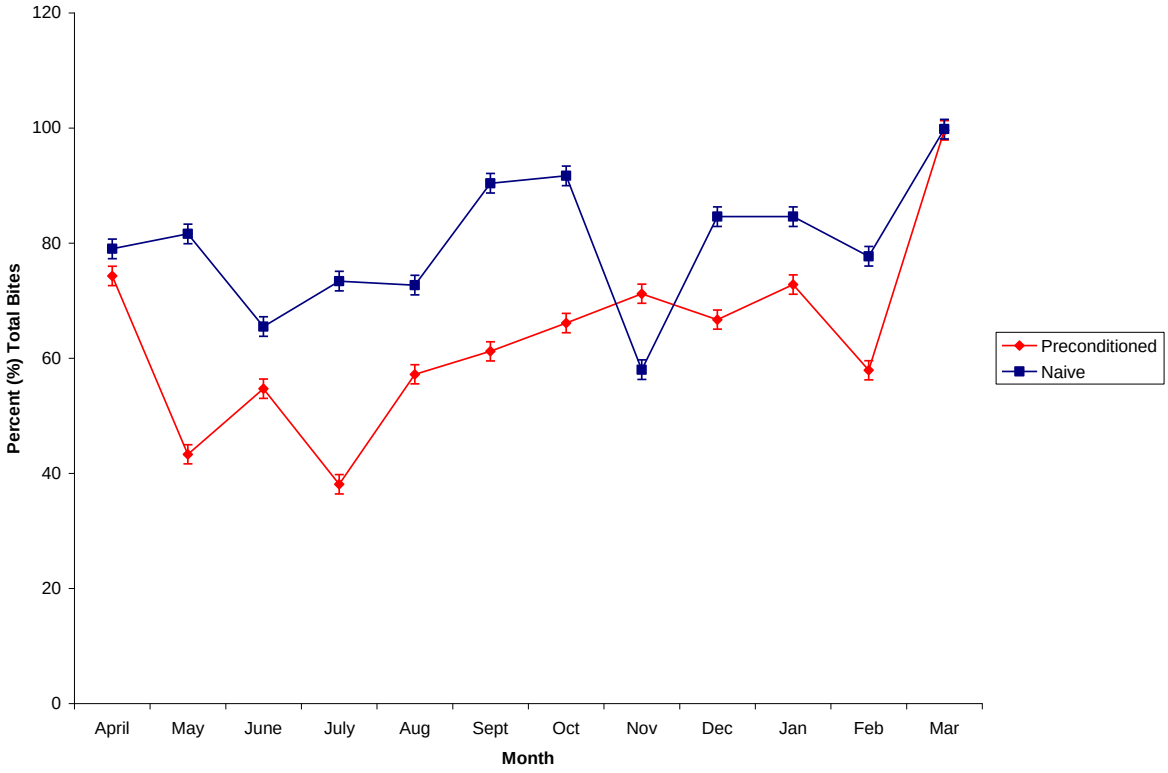

Figure 3. Preconditioned vs. naïve preference for herbaceous vegetation (percent of total bites) over 12 months of observations on pasture.

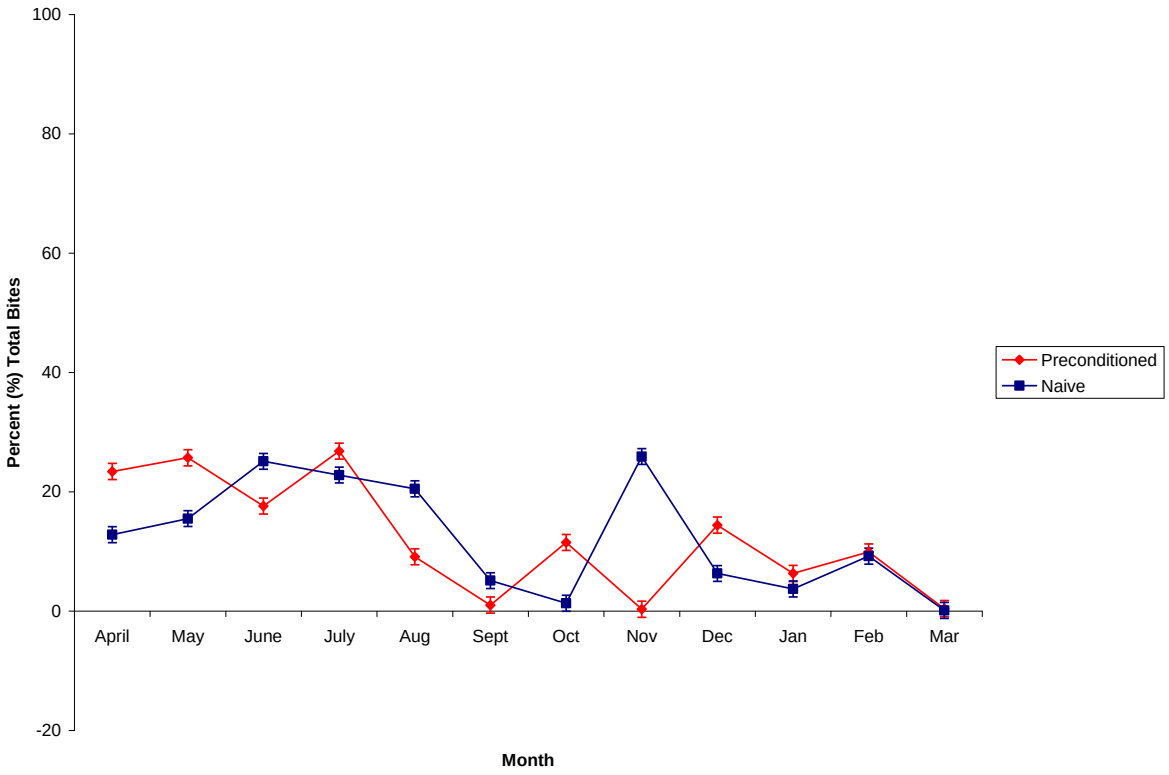

Figure 4. Preconditioned vs. naïve preference (percent of total bites) for other shrubs (e.g., liveoak, algerita, lotebush, persimmon) over 12 months of observations on pasture.

were also offered redberry juniper for a longer period than in previous studies which might have caused an immediate aversive feedback. This would cause the goats to consume less juniper during the feeding trial. In addition, terpene levels in juniper vary monthly and probably vary from year to year depending on ambient conditions (Owens et al. 1998a). The redberry juniper fed in the pre-conditioning phase of this study may have contained higher terpene levels than juniper fed in previous years.

The general consensus among ranchers and land managers is that goats will avoid juniper once released on pastures regardless of intake patterns in individual pens. Most would argue that goats will select nutritious herbaceous forages and shrubs and avoid juniper once released on pasture. The results of this study indicated Boer-cross female goats will consume redberry juniper at levels up to 40% on pasture when preconditioned for 14 days at weaning. Experiences early in life influence preferences later in life for both ruminants and non-ruminants (Provenza 1995, 1996). In some cases, exposure to toxic plants has resulted in increased preference and use (Distil and Provenza 1991; Walker et al. 1992; Olson et al. 1996). The mechanisms that allow ruminants to adapt to plants that cause aversive postingestive feedback and (or) toxicosis remain unclear. However, changes in rumen or liver function may result in adaptation to toxic forages (Weimer 1998). Previous studies have illustrated that the rumen function does not change to the point of detoxifying the terpenes in juniper (Dunson et al. 2006). However, there is some preliminary evidence showing increased enzymatic liver activity after feeding juniper for 14 days (Skiles et al., unpubl. data).

Goats typically avoid juniper during the spring and summer and when alternative herbaceous forage is available (terpene levels are higher) (Ellis et al. 2005). Preconditioned goats consumed juniper every month of this study. Intake varied monthly, which was probably in response to herbaceous forage quality, and terpene levels.

During observations, it was often difficult to distinguish if goats were consuming redberry or ashe juniper. It appeared that goats consumed more ashe than redberry juniper. Ashe juniper contains lower levels of terpenes and was preferred over redberry juniper in previous feeding trials (Pritz et al. 1997). During the January observations, browsed juniper plants in the two preconditioned pastures were identified. Approximately 84% of the browsed plants were ashe juniper. There did not appear to be a preference for male or female plants.

Naïve goats selected a diet that consisted primarily of herbaceous forage throughout the year. Selection of other browse plants was correlated with availability of herbaceous forage. As herbaceous forage decreased seasonally, naïve goats increased intake of other browse plants. Liveoak (data not presented) was the most preferred alternative forage.

SUMMARY AND IMPLICATIONS

Feeding juniper at weaning increases intake of juniper and goats will continue consuming some juniper on pastures even when alternative forage is available. Results of this study indicate that goats fed juniper at weaning will consume a diet that consists of juniper and

herbaceous forage while goats naïve to juniper will consume a diet consisting primarily of herbaceous forages.

Based on the results of this study, producers should feed juniper at weaning to replacement does to increase use of the plant. Fresh limbs of juniper could be hand-cut and placed in pens where replacement does are being weaned.

Once juniper is included in the diets of goats, the plant community dynamics and competitive dominance of the plant community should change. Juniper dominates rangelands in central and western Texas because it gains a competitive advantage over herbaceous forages and other shrubs that are consumed for forage while juniper is avoided (Archer 1994). In both preconditioned pastures, browse lines became apparent on mature junipers throughout both pastures and several immature junipers were defoliated (Fig. 8 and Fig. 9). Although it was not measured in this study, others have observed greater juniper seedling mortality when pastures were stocked with goats (C.A. Taylor, pers. comm.). Collectively, these results suggest that preconditioning goats to consume juniper should slow the invasion of juniper onto rangelands and create browse-lines on juniper allowing for increased herbaceous production below the canopies of the plant.

Finally, many land managers are left with few alternatives when dealing with juniper dominance. Mechanical and chemical control options are too costly (Johnson
et al. 1999). Prescribed burning can be a cost effective method of controlling juniper. However, there are several locations throughout central Texas where juniper dominates, but prescribed burning is not an option because of proximity to urban areas. Stocking preconditioned goats on rangelands in these areas may be the only cost effective option for managing juniper.

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EFFECT OF *SOLANUM DIMIDIATUM* ON EMBRYONIC LOSS AND NEONATAL LAMB SURVIVAL IN RAMBOUILLET SHEEP

Natalie E.A. Sato, Mike W. Salisbury, Cody B. Scott, Gil R. Engdahl

ABSTRACT

Thirty-six Rambouillet ewes were utilized to determine if ingestion of potato-weed (*Solanum dimidiatum*) causes abortion and the effects of potato-weed ingestion on newborn lamb health. Ewes were randomly assigned to one of four treatments (n = 10) and were placed on a feeding trial at days 80 to 101 of pregnancy. All treatments received a basal diet plus potato-weed at: 1) 0.1% of body weight, 2) 0.2% body weight, 3) 0.3% body weight, and 4) 0% of body weight; control. Ewe final weights and total weight gains differed among treatments ($P < 0.05$). Intake of ewes fed potato-weed differed among treatments and across days of feeding ($P < 0.05$). Lamb average birth weights, vigor scores, total gains, and weights taken every seven days were similar among treatments ($P > 0.05$). Serum progesterone concentrations of ewes did not differ amongst treatments ($P > 0.05$). Serum metabolite levels of total protein, blood urea nitrogen (BUN), total bilirubin, aspartate transaminase (AST), and gamma glutamyltransferase (GGT) were similar among treatments and across days of feeding ($P < 0.05$). Serum glucose levels differed among treatments ($P < 0.05$). Treatment by day interaction was observed for creatinine ($P < 0.05$). Results of this study indicate no abortive effects or hindered lamb health, however, plant toxicosis was evident by the decreased intake and elevated GGT levels.

INTRODUCTION

Reproductive inefficiency and losses resulting from poisonous plants are detrimental economic expenses for the livestock producer. Several poisonous plants have adverse effects on livestock reproduction leading to embryonic and/or neonatal death, abortion, and teratogenesis (Panter et al., 1992).

The Angelo State University Management, Instruction, and Research Center in San Angelo, Texas along with producers in the neighboring areas have encountered reproductive losses in the fall lambing Rambouillet flock for the past several years. In the Fall of 2004, all the ewes were pregnant, however, preliminary data collected from August to October (80 to 110 days of pregnancy) using ultrasonographic imaging displayed a 14% decrease in the number of pregnant ewes. The suspected culprit for the reproductive losses is a toxic plant known as potato-weed (*Solanum dimidiatum*) because ewes on these fields are grazing primarily sorghum sudan and the only other abundant plant present is potato-weed.

Multiple plant species and their accompanied toxins have been identified as causing abortions, teratogenesis, and neonatal death. Of these plant species, extensive studies have been conducted on false hellebore (*Veratrum californicum*) and locoweed (*Astragalus* spp.) identifying their teratogenic and abortive abilities, their toxins modes of action, and the timeline these disruptive events occur during digestion (Panter et al., 1992;

Keeler, 1988). However, according to Casteel et al. (1989) very little research has been conducted with *S. dimidiatum* and its teratogenic, abortive, and neonatal lamb effects since Menzies et al. (1979) reported an association with *S. dimidiatum* and a neurological disease in cattle. Therefore, this study will provide information on the abortive effects of *S. dimidiatum*, as well as neonatal lamb survivability. This study was designed to measure intake levels, serum metabolite levels indicative of toxicosis, incidence of abortions, progesterone levels of ewes, birth weight of lambs, and lamb vigor. Information ascertained from this study will provide further information in plant toxicology and its relationship to livestock reproduction.

MATERIALS AND METHODS

Seventy-six Rambouillet ewes were purchased in the month of April, placed on a balanced diet and observed to make sure all animals were healthy. Ewes were synchronized for estrous and joined with 4-5 rams in one group during the month of June. Breeding marks were collected daily, to determine the date of service, so that the 40 ewes required for data collection would be only 14 days different in gestation amongst them. Pregnancy was verified using ultrasonographic imagery at day 56 of gestation and every 14 days until parturition.

Plant material, *S. dimidiatum*, was collected, dried, and ground through a 2 mm screen 3 weeks prior to feeding coinciding with the 80–101 d of normally managed flock to facilitate feeding. A complete feed formulated at Angelo State University served as the basal diet of all ewes on the experiment. Thirty-six ewes (within 14 day gestation difference) were randomly assigned to one of four treatments (n = 9). Ewes were allowed a 7-day adaptation period to individual pens and testing environment. The four treatments were: Treatment 1: received basal diet plus *S. dimidiatum* at 0.1% BW from days 80 to 101 of gestation; Treatment 2: received basal diet plus *S. dimidiatum* at 0.2% BW from days 80 to 101 of gestation; Treatment 3: received basal diet plus *S. dimidiatum* at 0.3% BW from days 80 to 101 of gestation; Treatment 4: received only the basal diet to serve only as control. *S. dimidiatum* levels were chosen based on Cheeke's (1998) statement that ingesting 0.1 to 0.3% BW may cause toxic conditions. Feed intake and refusals were measured daily.

Serum metabolite levels indicative to toxicosis was collected every 72 hours using jugular venipuncture. Cornelius (1989) stated that toxicosis and liver damage can be detected by elevated blood serum levels of aminotransferase (AST), blood urea nitrogen (BUN), gamma glutamyl-transferase (GGT), and creatinine. Blood samples were collected by venipuncture, centrifuged, and serum was separated. Serum was frozen at 0°C until samples were shipped to Texas Veterinary Medical Diagnostic Laboratory, College Station, TX. Progesterone levels were obtained every 7 days to determine pregnancy as described by Schneider and Hallford (1996). All samples were analyzed in one assay and the intra-assay coefficient of variability (CV) was 9.4%.

On the last day of the feeding trial, ewe body weights were obtained. At the time of parturition, birth weights were collected and lamb vigor scores were assigned during the first 8 hours of life. Vigor scores were assessed on a scale of 0

to 5 as follows: 0 = dead; 1 = extremely weak, no attempt to get up or stand; 2 = struggles to get up, delay in nursing; 3 = slow to get up, slow to nurse; 4 = strong but slow to nurse; and 5 = strong, nurses rapidly. Body weights of lambs were collected at days 7, 14, 21, and 28 following parturition. Abortion incidences were also recorded throughout gestation.

Ewes were randomly assigned to treatment (n = 9/treatment). Ewes were individually penned and the individual ewe was the experimental unit. Single point data including ewe and lamb body weights and lamb vigor score were analyzed using analysis of variance (ANOVA) of SAS (SAS Institute Cary, North Carolina). Abortion incidences were analyzed using Chi Square of SAS. Intake and serum metabolite data were analyzed using repeated measures of analysis to compare differences among treatments with ewes nested within treatments as replications. Treatment differences were considered significant at ($P \leq 0.05$).

RESULTS

Initial weights of ewes were similar among treatments ($P > 0.05$; Table 1). However, ending weights differed among treatments. Treatments 2 and 3 had lower ($P < 0.05$) final weights than ewes in the control group (Treatment 4). Final weights of Treatment 1 ewes were similar to ewes in Treatment 3. Weight gains also varied among treatments (Table 1). Control and Treatment 1 had total gains similar to each other ($P > 0.05$). Total gains of ewes in Treatments 2 and 3 were similar to each other ($P > 0.05$) but differed from control and Treatment 1 ($P < 0.05$).

Lamb average birth weights, vigor scores, total gains, and weights taken every seven days were similar among treatments (Table 2). Two lambs from Treatment 1 ewes died shortly after parturition, in addition, one abortion involving twin lambs occurred within Treatment 1. Treatment 2 had multiple lamb deaths as well, two single lambs and one set of twins. These lambs from Treatment 2 were accessed a vigor score of 3 or less shortly after birth. Five lambs that were accessed with vigor scores less than 3 from Treatment 3 died shortly after birth. One abortion incident was also observed in Treatment 3. A lamb accessed with a vigor score of 3 from treatment 4 (control) died due to starvation.

Serum progesterone was collected every 7 d, however, samples for d 0, 7, 16, and 21 of the feeding trial were analyzed. Obvious trends were seen in the four collection days of the progesterone samples, therefore no further samples were analyzed. Serum progesterone concentrations of ewes did not differ amongst treatments ($P > 0.05$; Table 3). Serum progesterone levels increased throughout the gestational period, 5.31 ng/ml to 9.13 ng/ml, regardless of treatment group because of their physiological status. Initial and d 7 serum progesterone levels were also similar ($P > 0.05$). Collection times for d 16 and d 21 were different than initial and d 7 collection times. However, day 16 and d 21 serum progesterone concentrations were similar to each other ($P > 0.05$).

Intake of ewes fed potato-weed differed among treatments and across days of feeding (treatment x day interaction, $P < 0.05$; Fig. 1). Ewes fed the basal diet (control) and potato-weed at 0.1% BW consumed more potato-weed than ewes fed potato-weed at the 0.2% and 0.3% BW. Throughout the 21 d feeding trial, ewes fed potato-weed at 0.1% BW

Table 1. Mean initial, final, and total weight gains of ewes fed *S. dimidiatum* for 21 days at 0%, 0.1%, 0.2% and 0.3% of individual body weight

	Treatments[a]				
Item	1	2	3	4	SE[b]
Initial weight, kg	61.8	61.9	64.8	63.4	2.9
Final weight, kg	60.5[cd]	55.7[c]	54.9[c]	64.5[d]	2.3
Total gain, kg	-1.3[c]	-6.2[d]	-9.9[d]	1.1[c]	1.6

[a]Treatments were 1 = basal diet plus *S. dimidiatum* at 0.1% ewe body weight; 2 = basal diet plus *S. dimidiatum* at 0.2% body weight; 3 = basal diet plus *S. dimidiatum* at 0.3% ewe body weight; 4 = basal diet plus *S. dimidiatum* at 0% ewe body weight to serve as control.
[b]Standard error of the least squares means, n = 9.
[c,d]Means in the same row with different superscripts are different; $P < 0.05$.

Table 2. Mean birth weights, day 7, day 14, day 21, and day 28 weights of lambs born to ewes fed *S. dimidiatum* for 21 days

	Treatments[a]				
Item	1	2	3	4	SE[b]
N	9	7	10	10	
Vigor score	4.5	3.6	3.7	4.4	0.5
Birth weight, kg	4.4	3.9	4.2	4.9	0.5
Day 7, kg	6.1	6.4	6.9	7.6	2.9
Day 14, kg	8.6	8.0	8.3	9.2	1.2
Day 21, kg	11.6	10.9	11.1	12.0	1.5
Day 28, kg	14.7	13.2	13.6	13.9	1.6
Total gain, kg	10.2	9.0	9.1	9.4	1.5

[a]Treatments were 1 = basal diet plus *S. dimidiatum* at 0.1% ewe body weight; 2 = basal diet plus *S. dimidiatum* at 0.2% body weight; 3 = basal diet plus *S. dimidiatum* at 0.3% ewe body weight; 4 = basal diet plus *S. dimidiatum* at 0% ewe body weight to serve as control.
[b]Standard error of the least squares means.

Table 3. Mean serum progesterone concentrations for ewes fed 0%, 0.1%, 0.2%, and 0.3% *S. dimidiatum* of body weight for 21 days

	Treatments[a]				
Item	1	2	3	4	SE[b]
d 120, ng/ml	5.9	5.3	4.8	5.2	0.8
d 127, ng/ml	5.7	5.4	4.9	4.5	0.7
d 136, ng/ml	8.4	9.0	7.6	5.9	1.5
d 141, ng/ml	8.6	11.1	9.8	7.1	1.8

[a]Treatments were 1 = basal diet *plus S. dimidiatum* at 0.1% ewe body weight; 2 = basal diet plus *S. dimidiatum* at 0.2% body weight; 3 = basal diet plus *S. dimidiatum* at 0.3% ewe body weight; 4 = basal diet plus *S. dimidiatum* at 0% ewe body weight to serve as control.
[b]Standard error of the least squares means, n = 9.

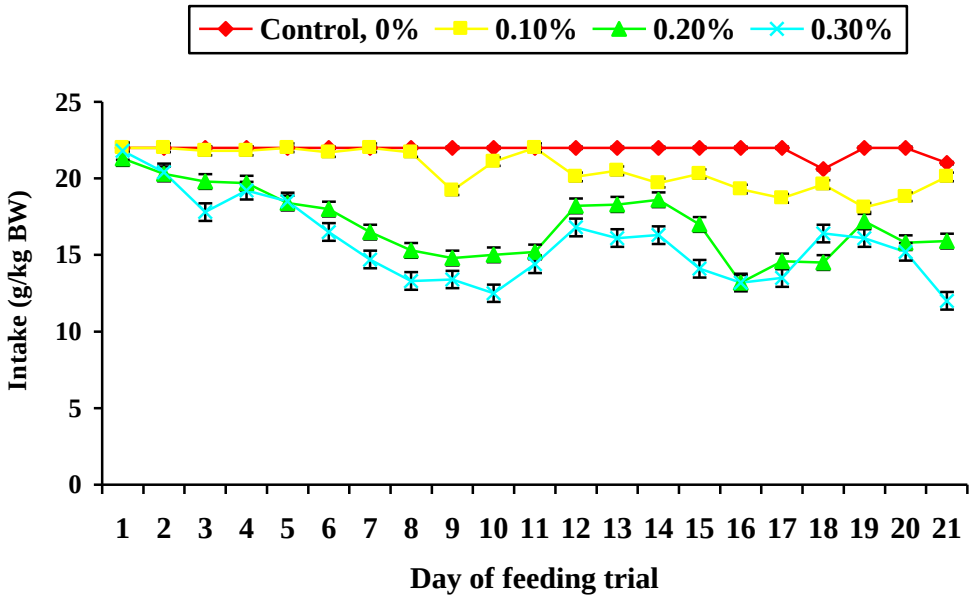

Figure 1. Average intake (g/kg BW) for ewes fed 0%, 0.1%, 0.2%, and 0.3% *S. dimidiatum* of body weight for 21 days

consumed on average 20.6 g·kg^{-1} BW per day. However, consumption decreased on day 9 to 19.2 g·kg^{-1} BW per day followed by an increase in intake the following day to 21.1 g·kg^{-1} BW showing a moderate cyclical pattern of intake. Ewes fed potato-weed at 0.2% and 0.3% BW displayed a drastic cyclical pattern of intake over the 21 day feeding trial. However, consumption for both groups was still less than their initial consumption.

Serum metabolites were collected every 72 h, however, samples for d 0, 13, and 21 of the feeding trial were analyzed. No obscure trend was seen in the three collection days of the metabolite samples, therefore no further samples were analyzed. Serum metabolite levels of total protein, BUN, total bilirubin, AST, and GGT were similar among treatments and across days of feeding (Table 4).

Serum glucose levels differed among treatments ($P < 0.05$). Ewes from Treatments 2 and 3 had similar glucose levels and levels were lower compared to Treatments 1 and 4. Treatment 4 had the highest glucose level amongst all the treatments. Treatment 1 had glucose levels in between that of Treatment 4 and Treatments 2 and 3.

Treatment by day interaction was observed for creatinine ($P < 0.05$; Table 5). On average, Treatment 1 ewes had an initial serum creatinine level of 0.71 mg/dl. By days 133 and 141 of gestation, average serum creatinine levels increased to 0.78 mg/dl and 0.86 mg/dl, respectively. Treatment 2 ewes had an average initial serum creatinine level of 0.73 mg/dl. An increase in serum creatinine for days 133 and 141 of gestation was observed at 0.83 mg/dl and 0.92 mg/dl, respectively. Initial serum creatinine levels for Treatment 3 ewes were measured at 0.70 mg/dl with day 133 of gestation being measured at 0.93 mg/dl. However, by day 141 of gestation creatinine levels decreased slightly to 0.91 mg/dl. The control group had initial serum creatinine levels at 0.74 mg/dl. Creatinine levels for this group remained constant at 0.86 mg/dl for 133 and 141 days of gestation collection periods.

DISCUSSION

Decreased intake of ewes fed potato-weed at 0.2% and 0.3% of body weight were observed by d 2 of the feeding trial followed by a progressive decrease by d 6. Conversely ewes fed potato-weed at 0.1% of body weight had a consistently higher level of intake followed by a cyclic pattern of intake by day 9 of the feeding trial. Decreased overall intake resulted in substantially lower body weights of ewes in treatments 2 and 3. Provenza (1995) stated that animals will eat nutritious plants containing toxins, however, because of aversive postingestive feedback from many toxins, they limit their intake of that plant. The discomfort that animals feel from eating the toxic plants, particularly the glycoalkaloids of potato-weed, apparently caused a decrease in intake (Provenza, 1995).

No teratogenic effects were observed in lambs of this study. In addition, lamb average birth weights, vigor scores, total gains, and weights taken every seven days were similar among treatments ($P > 0.05$). Malformations may not have been observed because certain types of malformations by toxicants

Table 4. Mean serum metabolite concentrations for ewes fed 0%, 0.1%, 0.2%, and 0.3% *S. dimidiatum* of body weight for 21 days

	Treatments[a]				
Item	1	2	3	4	SE[b]
Total protein, g/dl	7.237	6.789	7.089	6.941	0.205
Glucose, mg/dl	57.04[c]	51.56[d]	52.48[d]	59.74[e]	2.098
BUN mg/dl	15.26	16.97	15.91	16.06	0.849
Creatinine, mg/dl	0.781	0.830	0.848	0.826	0.322
Total bilirubin, mg/dl	0.104	0.126	0.122	0.104	0.015
AST, U/l	62.22	78.55	89.15	60.19	13.096
GGT, U/l	66.81	63.41	65.93	61.85	4.915

[a]Treatments were 1 = basal diet plus *S. dimidiatum* at 0.1% ewe body weight; 2 = basal diet plus *S. dimidiatum* at 0.2% body weight; 3 = basal diet plus *S. dimidiatum* at 0.3% ewe body weight; 4 = basal diet plus *S. dimidiatum* at 0% ewe body weight to serve as control.
[b]Standard error of the least squares means, n = 9.
[c,d,e]Means in the same row with different superscripts are different; $P < 0.05$.

Table 5. Treatment by day interaction of mean serum creatinine concentrations for ewes fed 0%, 0.1%, 0.2%, and 0.3% *S. dimidiatum* of body weight for 21 days

	Treatments[a]			
Item	1	2	3	4
d 120, mg/dl	0.71[fg]	0.73[fh]	0.70[g]	0.74[h]
d 133, mg/dl	0.78[e]	0.83[d]	0.93[b]	0.87[c]
d 141, mg/dl	0.86[cd]	0.92[b]	0.91[b]	0.87[c]

[a]Treatments were 1 = basal diet *plus S. dimidiatum* at 0.1% ewe body weight; 2 = basal diet plus *S. dimidiatum* at 0.2% body weight; 3 = basal diet plus *S. dimidiatum* at 0.3% ewe body weight; 4 = basal diet plus *S. dimidiatum* at 0% ewe body weight to serve as control.
[b,c,d,e,f,g,h]Means with different superscripts are different; $P < 0.05$; standard error of the mean = 0.025.

appears to be related to specific periods in fetal development, fetal movements (Panter et al., 1992). For example, cleft palate in sheep and goats occurs around d 30 to 38 of gestation when the tongue is visible and the plate fuses. Multiple congenital contractures (MCC) occurs at d 40 to 60 of gestation when fetal movement is at its peak and normal bone elongation, tendon, ligament, and muscle development is dependent on normal fetal movement (Panter et al., 1992). Ewes ingesting false hellebore (*Veratrum californicum*) on d 14 of gestation exhibited lambs with facial defects resulting from neural tube defects and a high incidence of embryonic death (Panter et al., 1992). Ewes in this study were fed potato-weed at d 80 to 101 of gestation. Apparently this period of gestation for ingestion of potato-weed had no effect on fetal development, movement, or heart activity to cause higher abortion incidences, teratogenic effects, or hinder lamb survivability.

An increase in serum progesterone concentrations was observed in this study. Although blood samples utilized for serum progesterone were collected every 7 d, progesterone levels of samples from d 120, 127, 136, and 141 of gestation were run. The results from these serum progesterone levels did not show a pattern other than the increasing progesterone level throughout collection times. According to Schneider and Hallford (1996), plasma progesterone increases between d 50 and 120 of gestation in sheep. In addition, in the last 50 d of gestation, ewes carrying twins have twice the amount of progesterone as ewes carrying single lambs. Mean serum progesterone concentrations of all ewes, regardless of treatment group, had levels above 2.4 ng/ml indicating no abortions; all ewes had lambs. This evidence is supported by results presented by Schneider and Hallford (1996) when they predicted pregnancy in ewes utilizing a commercial radioimmunoassay (RIA) kit to quantify serum progesterone. The research conducted by Schneider and Hallford further extrapolated progesterone values for non-pregnant ewes (serum progesterone concentration $\leq$ 2.4 ng/ml); ewes with single lambs (serum progesterone concentration $\geq$ 2.5 ng/ml but $\leq$ 10.9 ng/ml); and ewes with two or more lambs (serum progesterone concentration $\geq$ 11.0 ng/ml). In addition, the moderate levels of serum progesterone seen in this study is opposite of what Ellis et al. (1985) found when ewes were fed locoweed (*Astragalus lentiginosus*). Results from their study showed mean serum progesterone levels at 2.80 $\pm$ 0.13 ng/ml indicating hindered corpus luteum and or cotyledonary function.

No differences in serum metabolite levels for total protein, BUN, total bilirubin, AST, and GGT were seen among treatments or across days of feeding. In addition, these serum metabolite levels fell within the normal range reported for sheep (Aiello, 1998). Serum GGT concentrations were well above the normal range of sheep. This study showed a GGT range of 61.85 U/l to 66.81 U/l. The normal range for sheep serum GGT is 19.6 U/l to 44.1 U/l (Aiello, 1998). The high levels measured in this study may indicate disruption to the liver and its associated functions (HealthCheck Labs, 1997).

A treatment by day interaction was measured for serum creatinine concentrations ($P < 0.05$). Creatinine levels tended to be lower, ranging from 0.7 to 0.93 mg/dL, than the normal range

reported for sheep (0.9 to 2.0 mg/dL; Aiello, 1998). Renal failure is a result of toxic plant ingestion and is accompanied with elevated BUN and creatinine levels (Aiello, 1998). Renal failure was not evident from the normal BUN values and slightly lower creatinine levels.

Serum glucose levels differed among treatments; however, mean glucose levels were within the normal range. It is suspected that the treatment interaction for glucose was from the variation of intake of the ewes in this study. A study conducted by Menzies et al. (1979) observed no significant changes in blood glucose when 6 calves were dosed via rumen cannula with *S. dimidiatum*. Although no changes in blood glucose were observed, Menzies et al. (1979) further reported a significant weight loss of all calves involved in the study indicating decreased intake. Ewes in this study had decreased intake and elevated GGT levels indicating plant toxicosis.

Abortions observed in previous years at Angelo State University Management, Instruction, and Research Center in San Angelo, TX along with producers in the neighboring areas may be due to increased summer temperatures hindering the reproductive capabilities of ewes. In addition, potato-weed may be causing abortions when ewes are ingesting the plant shortly before pregnancy or within the early stages of pregnancy (i.e. around days 30-45 of gestation). Further more, potato-weed may cause abortions when consumed over a long period of time resulting in a cumulated effect when consumed at low levels.

IMPLICATIONS

The results observed in this study indicate that *S. dimidiatum* does not cause abortions, teratogenic effects, or hinder newborn lamb health when ewes were fed the plant during days 80 to 101 of gestation. However, plant toxicosis was evident by the decreased intake and elevated GGT levels.

Further studies implementing *S. dimidiatum* to induce abortions, teratogenic effects, or hinder newborn lamb health need to be examined. Timing of dosing in this study may have been a factor as to why no abortions or teratogenic effects occurred. Dosing of *S. dimidiatum* may need to be implemented within the earlier stages of gestation to have an effect on reproduction and lamb survivability.

Producers should remain cautious when grazing hay-grazer fields when potato-weed is present even though the mechanism causing abortions was not identified.

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CONTROLLING MESQUITE USING THE HERBICIDE REDEEM

Corey J. Owens, Cody B. Scott, and Timothy H. Dietz

ABSTRACT

Two experiments were conducted to determine the mortality rate of mesquite (*Prosopis glandulosa*) after spraying with the herbicide Redeem. In Experiment 1, mortality rates were compared for mesquite trees sprayed with three different concentrations of Redeem while in Experiment 2, mortality rates of trees treated with varying mixtures of Reclaim, Remedy, and Redeem were evaluated. Nine transects (3 transects/treatment) consisting of 10 mesquite trees each were sprayed with 1%, 2%, or 3% Redeem concentrations. Nine additional transects consisting of 10 mesquite trees each were sprayed with 1% Reclaim, 2% Redeem, or 0.5% Remedy + 0.5% Reclaim. Mortality rates for each treatment were calculated based on the number of dead trees three years after treatment. Mortality rates were similar ($P>0.05$) among treatments. Spraying with 1% Redeem resulted in a 73% mortality rate while 2% and 3% Redeem mortality rates were 51% and 68%, respectively. It appears that increasing the Redeem concentration above 1% does not improve mortality rates. Mortality rates for trees sprayed with 2% Redeem were lower (66%) than for trees sprayed with 1% Reclaim or 0.5% Reclaim with 0.5% Remedy. Results indicate that 1% Reclaim or 0.5% Remedy, 0.5% Reclaim mixture have considerably higher kill rates than 2% Redeem.

INTRODUCTION

Honey mesquite (*Prosopis glandulosa*) is an invasive problematic plant found throughout the southwestern United States (Meyer et al. 1971). Mesquite out-competes herbaceous forage. It is chemically-defended and rarely consumed by livestock. The plant produces large amounts of seeds annually, even during drought conditions which are common in central and western Texas (Fisher et al. 1959). Despite considerable control efforts, mesquite continues to be the dominant shrub on almost 54 million acres of rangelands in Texas (Jacoby et al. 1990). These efforts include both chemical and mechanical control methods. Both control methods are effective but typically are not economically feasible because of cost and rapid re-establishment of mesquite. Hand-spraying is commonly recommended to slow the rate of re-establishment of mesquite. Unfortunately, little is known regarding the most practical herbicide mixture for controlling mesquite re-establishment.

Three herbicides are currently available for control of mesquite. These are Remedy, Reclaim, and Redeem. Remedy is an ester-based herbicide composed of 61.6% Triclopyr as the active ingredient. Reclaim is an amine-based herbicide consisting of 40.9% Clopyralid as the active ingredient, and Redeem is a combination of both Triclopyr and Clopyralid (33% and 12.1%, respectively). Because the two active ingredients used for the control of mesquite are in a premixed solution in Redeem, the convenience of this herbicide is making it more popular among landowners.

The objectives of these studies were to compare the mortality rates of trees sprayed with three different concentrations of Redeem and compare

mortality rates of those trees treated with varying mixtures of Reclaim, Remedy, and Redeem.

METHODS

Two separate experiments were conducted to evaluate the efficacy of Redeem. Experiment 1 measured the difference in mesquite mortality as a function of Redeem concentration while Experiment 2 measured the difference in mesquite mortality after spraying with Redeem, Reclaim, or a mixture of Remedy and Reclaim. In each experiment, 9 transects each consisting of 10 mesquite trees (< 6 ft tall) were established on sites previously cleared of mesquite (root plowed in 1974) located on Angelo State University's Management, Instruction, and Research Center. All sites were located in similar areas characterized by Angelo Clay Loam soils. Herbaceous cover on the site consisted of a mixture of sideoats grama (*Bouteloua curtipendula*), sand dropseed (*Sporobolus cryptandrus*), KR bluestem (*Bothrichloa ischaemum*), silver bluestem (*Bothrichloa laguroides*), and Kleingrass (*Panicum coloratum*).

Trees within transects were measured and individually tagged. Transects served as replications and each tree served as an experimental unit. Transects in Experiment 1 were randomly allocated one of three treatments and treated with either a 1%, 2%, or 3% concentration of Redeem. Redeem was mixed with 0.25% Herbimax® surfactant, 0.25% Hi-Light® blue dye, and water. The trees in each transect were then sprayed using the leaf spray method of mesquite control outlined by the Brush Busters Brush Control Program (1996). Trees were sprayed during June of 2002. Wind speed was approximately 10 mph with air temperatures near 95° F. We delayed spraying until all of the foliage on trees was dark green and no flowers or fruit were evident. When mesquite trees are actively growing, flowering, or producing fruit, mortality rates decline.

Transects in Experiment 2 were randomly allocated one of three treatments: 1% Reclaim (Clopyralid), 2% Redeem (Clopyralid and Triclopyr), or 0.5% Remedy (Triclopyr) + 0.5% Reclaim (Clopyralid). Each mixture also consisted of 0.25% Herbimax® surfactant, 0.25% Hi-Light® blue dye, and water. The trees in each transect were sprayed using the leaf spray method of mesquite control outlined by the Brush Busters Brush Control Program (McGinty and Ueckert 1996). Trees were sprayed at the same time and under the same conditions as in Experiment 1.

Mortality rates were compared among treatments within each experiment by counting the number of alive and dead trees three years after spraying. Data was analyzed using the statistical package JMP (SAS 1994) as a completely randomized design with spray mixture or concentration serving as the treatment and transects nested within treatments as replications. Differences between means were separated using least significant difference (LSD) when $P<0.05$.

RESULTS AND DISCUSSION

Mesquite trees are considered dead after three years of defoliation. Therefore, mortality rates between the varying concentrations of Redeem in Experiment 1 were compared during the third year of data collection. Mortality rates were similar ($P>0.05$) among treatments (Figure 1). Spraying with 1% Redeem resulted in a 73 % mortality rate while 2% and 3% Redeem mortality rates were 51% and 68 %, respectively. Currently, there is no

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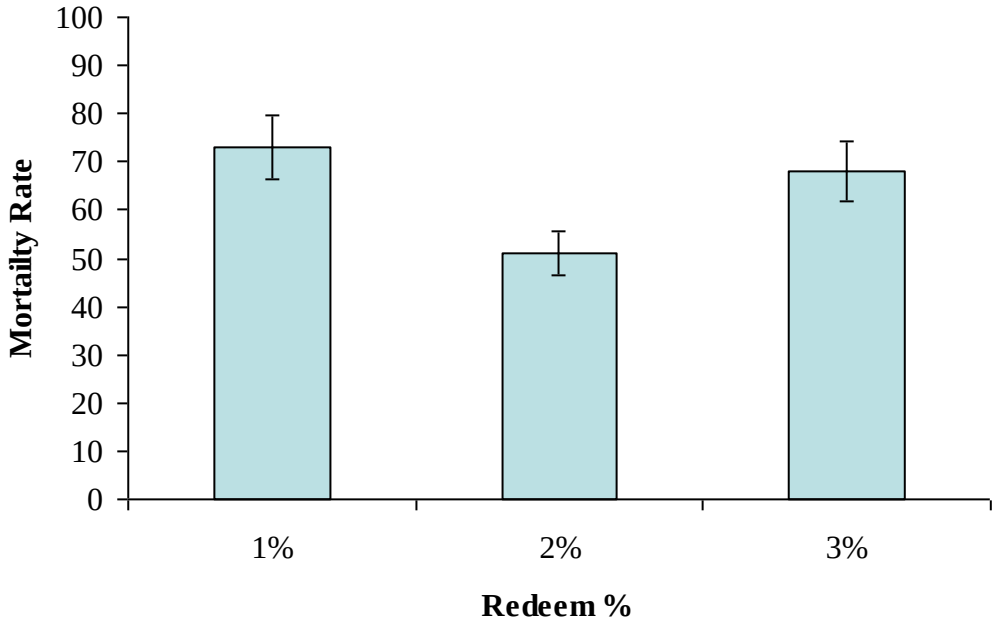

Figure 1. Mortality rates of mesquites between concentrations of Redeem in the three years after spraying. Trees were sprayed with 1%, 2%, or 3% Redeem mixed with water and a surfactant (0.25%).

recommended rate for spraying mesquite with Redeem. From this study, it appears that increasing the Redeem concentration above 1% does not improve mortality rates.

In Experiment 2, mortality rates for trees sprayed with 2% Redeem were significantly lower (66 %) than for trees sprayed with 1% Reclaim or 0.5% Remedy + 0.5% Reclaim (Figure 2). In other studies, combining Clopyralid and Triclopyr resulted in higher canopy reduction and overall mortality rate in honey mesquite trees than Clopyralid alone (Bovey et al. 1998). In order to reduce treatment costs while not affecting overall herbicide effectiveness, equal parts of Triclopyr can be added to herbicide mixtures (Bovey and Meyer 1985, Bovey and Whisenant 1991).

MANAGEMENT IMPLICATIONS

Because the results of Experiment 1 indicate no differences among treatments, increased percentages of Redeem will not result in higher mesquite mortality rates. From a management perspective, using a 1% concentration of Redeem will obtain a comparable kill rate to higher percentages while costing less. The results of Experiment 2 reveal that a 1% Reclaim or 0.5% Remedy + 0.5%

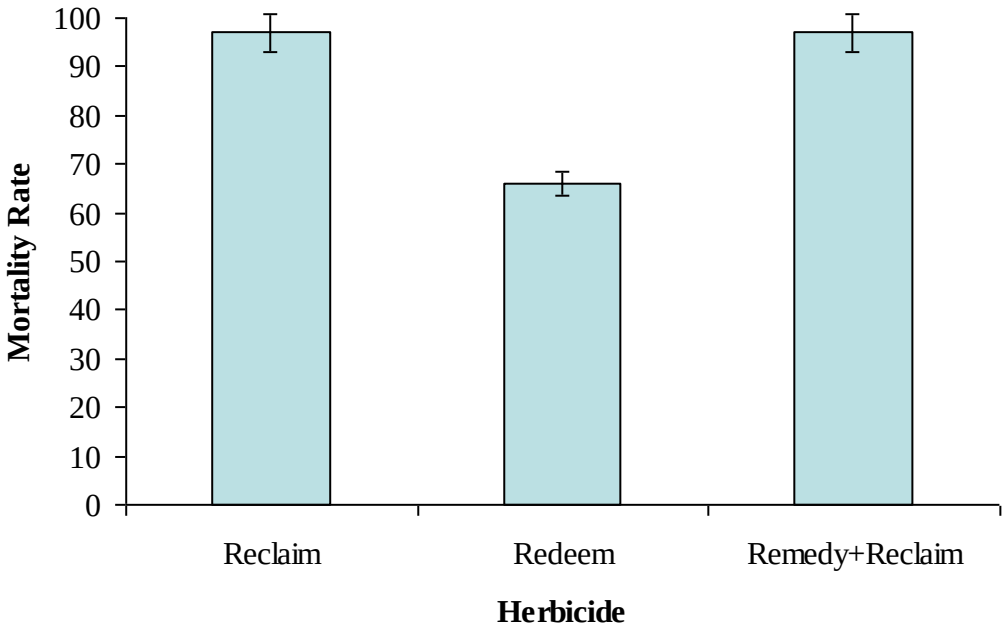

Figure 2. Mortality rates of mesquites between varying mixtures of herbicides in the three years after spraying. Trees were sprayed with 1% Reclaim, 2% Redeem, or 0.5% Remedy mixed with 0.5% Reclaim. All herbicide mixtures were mixed with water and a surfactant (0.25%).

Reclaim mixture have considerably higher kill rates than 2% Redeem. Therefore, producers may consider spraying with either one of these mixtures to obtain the desired mesquite control. Because Reclaim is more costly ($209.00 per gallon) than Remedy ($92.15 per gallon), using the mixture of the two herbicides may be the most economically feasible approach to mesquite control. In addition, the inclusion of Remedy typically improves mortality rates (Bovey and Whisenant 1991, Bovey et al. 1998). The one exception may be during droughts. In another study, mixing Remedy with Reclaim reduced translocation of Reclaim with mesquite trees were water-stressed (Roche et al. 2002). When mesquite trees are water-stressed, using a 1% Reclaim mixture may improve mortality rates over a 0.5% Remedy/0.5% Reclaim mixture.

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CONTROLLING MESQUITE USING THE HERBICIDE RECLAIM

Corey J. Owens, Cody B. Scott, Rob W. Cook, and Wayne T. Dunson

ABSTRACT

Varying mixtures of Reclaim, Remedy, and 2,4,D herbicides were applied to honey mesquite (*Prosopis glandulosa*) trees, and mortality rates were compared three years after spraying. Nine transects (3 transects/treatment) consisting of 10 mesquite trees each were hand-sprayed with 1% Reclaim, 0.5% Reclaim + 0.5% 2,4,D, or 0.5% Reclaim + 0.5% Remedy. Mortality rates for each treatment were calculated based on the number of dead trees three years after treatment. Mortality rates were similar ($P>0.05$) among all mixtures. Mortality rates ranged from 93 to 96% three years after spraying. Results indicate that diluting the concentration of Reclaim ($209 per gallon) with Remedy ($93 per gallon), or with 2,4,D, ($31 per gallon), reduces herbicide costs while maintaining control.

INTRODUCTION

The ever-increasing density of mesquite (*Prosopis glandulosa*) across the already 54 million ac of infested rangeland continues to reduce herbaceous production and cause problems for landowners (Bedunah and Sosebee 1984, Cuda and DeLoach 1998, Jacoby et al. 1990). Because mesquite is chemically-defended and rarely consumed by livestock, it out competes herbaceous forage for water and nutrients. As a result, landowners are constantly searching for ways to slow mesquite encroachment on rangelands. These efforts include both chemical and mechanical control methods which are effective, but longevity of control is often limited by rapid re-establishment of mesquite. One solution is to hand-spray immature mesquite trees to slow the rate of re-invasion. Landowners commonly rely on one of two methods developed through the Brush Busters program. One method relies on spraying the lower 12 inches of each stem with a mixture of Remedy and diesel. The other method relies on spraying the foliage with a mixture of Remedy and Reclaim. However, some producers prefer to spray with a solution of Reclaim without Remedy even though the mixture is more costly. Others suggest that similar mortality rates can be achieved using a mixture of Reclaim and 2,4,D, but data supporting this observation is not available.

Reclaim is an amine-based herbicide consisting of 40.9% Clopyralid as the active ingredient. Remedy is an ester-based herbicide composed of 61.6% Triclopyr as the active ingredient. Both herbicides are used for hand-spraying mesquite foliage. Mortality rates are high when 1% Reclaim is mixed with water and a surfactant. Likewise, mixing 0.5% Reclaim and 0.5% Remedy with water and a surfactant results in high mortality rates. The latter mixture is the most commonly recommended mixture because of lower cost of application. Reclaim cost $209 per gallon while Remedy cost $93 per gallon. Using Remedy in conjunction with Reclaim reduces the amount of Reclaim used by ½. Currently, there is not a recommended mixture of Reclaim and

2,4,D for hand-spraying mesquite. The objective of this study was to compare the mortality rates of mesquite trees sprayed with Reclaim alone, Reclaim mixed with Remedy, and Reclaim mixed with 2,4,D.

METHODS

Nine transects each consisting of 10 mesquite trees (< 6 ft tall) were established on sites previously cleared of mesquite (cleared in 1974) on the Angelo State University's Management, Instruction, and Research Center. All sites were located in similar areas characterized by Angelo Clay Loam soils. Herbaceous cover on the site consisted of a mixture of sideoats grama (*Bouteloua curtipendula*), sand dropseed (*Sporobolus cryptandrus*), KR bluestem (*Bothrichloa ischaemum*), silver bluestem (*Bothrichloa laguroides*), and Kleingrass (*Panicum coloratum*).

Trees within transects were measured and individually tagged. Transects served as replications and individual trees served as an experimental unit. Transects were then randomly allocated one of three treatments: 1% Reclaim, 0.5% Reclaim + 0.5% 2,4,D, or 0.5% Reclaim + 0.5% Remedy. Each mixture was combined with 0.25% Herbimax® surfactant, 0.25% Hi-Light® blue dye, and water. The trees in each transect were then sprayed using the leaf spray method of mesquite control outlined by the Brush Busters Brush Control Program (McGinty and Ueckert 1996). Trees were sprayed during June of 2002. Wind speed was approximately 10 mph with air temperatures near 95° F. We delayed spraying until all of the foliage on trees was dark green and no flowers or fruit were evident.

Mortality rates were compared among treatments by counting the number of alive and dead trees three years after spraying. Data was analyzed using the statistical package JMP (SAS 1994) as a completely randomized design with spray mixture or concentration serving as the treatment and transects nested within treatments as replications. Differences between means were separated using least significant difference (LSD) when $P<0.05$.

RESULTS AND DISCUSSION

Mortality rates among treatments were similar ($P>0.05$) three years after spraying (Figure 1). Spraying with 1% Reclaim resulted in a 96% mortality rate while spraying with 0.5% Reclaim/0.5% Remedy or with 0.5% Reclaim/0.5% 2,4,D resulted in a 93% and 96% mortality rate, respectively. In other studies, combining Clopyralid and Triclopyr resulted in higher canopy reduction and overall mortality rate in honey mesquite trees than Clopyralid alone (Bovey and Whisenant 1991, Bovey et al. 1998). Similarly, Jacoby et al. (1991), found that Triclopyr/Clopyralid mixtures resulted in greater overall plant mortality than Triclopyr or Triclopyr/Picloram mixtures. Thus, most rangeland managers recommend utilizing a 0.5% Reclaim/0.5% Remedy when hand-spraying mesquite using the leaf spray method. However, mortality rates may drop during droughts. There is some evidence that Remedy may decrease translocation of Reclaim when mesquite trees are water stressed (Roche et al. 2002). Under these circumstances, land managers may want to use a 1% Reclaim mixture to achieve acceptable mortality rates.

Results from this study regarding hand-spraying with a Reclaim/2,4,D mixtures are encouraging. However, land managers should be cautious about using

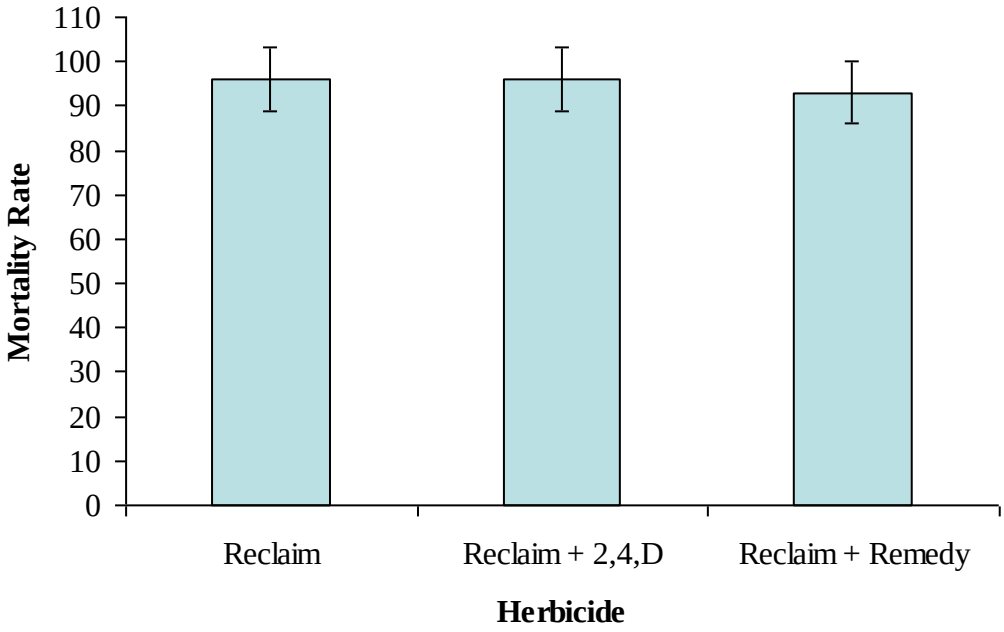

Figure 1. Mortality rates of mesquites between varying mixtures of herbicides three years after spraying with a 1% Reclaim mixture, 0.5% Reclaim mixed with 0.5% 2,4,D, or 0.5% Reclaim mixed with 0.5% Remedy. All mixtures were mixed with water and a surfactant (0.25%).

this mixture given limited amount of data available on mortality rates. The of this study may have differed if it was done on other sites or in other years.

MANAGEMENT IMPLICATIONS

As the results of this study indicate, there is no difference in mortality rates between spraying mesquite trees with 1% Reclaim or 0.5% Reclaim + 0.5% Remedy. Due to the high price of Reclaim ($209 per gallon), decreasing the concentration by half and mixing with Remedy ($93 per gallon) will reduce the overall cost of spraying while not adversely effecting tree mortality rates. Because of the rapid re-invasion/encroachment of mesquite on to grasslands, producers are encouraged to hand-spray mesquite regularly to maintain rangeland productivity and diversity.

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CONTROLLING MESQUITE USING THE HERBICIDE REMEDY

Corey J. Owens, Cody B. Scott, Haley J. Babb, and Bobby E. Deeds

ABSTRACT

Mortality rates from spraying mesquite (*Prosopis glandulosa*) with Remedy and Remedy Ready to Use (RTU) were compared three years after spraying. Nine transects (3 transect/treatment) consisting of 10 mesquite trees each were sprayed with 15% Remedy + 85% diesel, Remedy RTU, or 15% Remedy + 85% water. Mortality rates for each treatment were calculated based on the number of dead trees three years after treatment. Mortality rates were similar (P>0.05) among 15% Remedy + 85% diesel and Remedy RTU. Both treatments resulted in a 100% mortality rate three years after spraying. However, mortality rates for trees sprayed with 15% Remedy + 85% water were significantly lower (38%). Results indicate that 15% Remedy + 85% diesel, Remedy RTU will obtain comparable, effective kill rates on mesquite trees. Remedy RTU is more costly than Remedy + diesel; however, the convenience and effectiveness of this ready to use herbicide could make it a popular choice among landowners, particularly those that own small parcels of property.

INTRODUCTION

Honey mesquite (*Prosopis glandulosa*) has encroached upon 54 million ac of rangeland throughout Texas and has resulted in a decrease in herbaceous production (Cuda and DeLoach 1998). Mesquite can tolerate drought conditions common to west Texas (Fisher et al. 1959) by rapidly penetrating its roots deep into the soil and out competing grasses and other browse species for moisture (Brown and Archer 1990). It is also chemically defended and rarely consumed by livestock. Because of its dominance, landowners are searching for ways to slow encroachment.

Several herbicides are available for mesquite control. Remedy, an ester-based herbicide composed of 61.6% Triclopyr as the active ingredient, is one such herbicide approved for mesquite control. It is also found in a premixed, ready to use form known as Remedy RTU, and the convenience of this herbicide is making it more popular among landowners. Remedy is most often used in combination with diesel and applied basally to single-stemmed mesquite trees for control. However, as a more cost effective approach, it can be combined with water and an emulsifier. The objective of this study was to compare the mortality rates of mesquite trees sprayed with Remedy mixed diesel, Remedy RTU and Remedy mixed with water.

METHODS

Nine identically sized transects each consisting of 10 mesquite trees (< 6ft tall) were established on sites previously cleared of mesquite (cleared in 1974) located on the Angelo State University's Management, Instruction, and Research Center. All sites were located in similar areas characterized by Angelo Clay Loam soils. Herbaceous cover on the site consisted of a mixture of sideoats grama (*Bouteloua curtipendula*), sand dropseed

(*Sporobolus cryptandrus*), KR bluestem (*Bothrichloa ischaemum*), silver bluestem (*Bothrichloa laguroides*), and Kleingrass (*Panicum coloratum*).

Trees within transects were measured and individually tagged. Transects served as replications and each tree served as an experimental unit. Transects were then randomly allocated one of three treatments: 15% Remedy + 85% diesel, Remedy RTU (ready to use), or 15% Remedy + 85% water. Each mixture other than Remedy RTU was combined with 0.25% Herbimax® surfactant, and 0.25% Hi-Light® blue dye. An emulsifier was also added to the Remedy + water mixture to ensure proper dispersal. The trees in each transect were then sprayed using the basal stem spray method of mesquite control outlined by the Brush Busters Brush Control Program (McGinty and Ueckert 1996). Trees were sprayed during June of 2002. Wind speed was approximately 10 mph with air temperatures near 95° F. We delayed spraying until all of the foliage on trees was dark green and no flowers or fruit were evident. When mesquite trees are actively growing, flowering, or producing fruit, mortality rates decline.

Mortality rates were compared among treatments by counting the number of alive and dead trees three years after spraying. Data was analyzed using the statistical package JMP (SAS 1994) as a completely randomized design with spray mixture or concentration serving as the treatment and transects as replications.

RESULTS AND DISCUSSION

Mortality rates were similar ($P>0.05$) for trees sprayed with15% Remedy + 85% diesel and Remedy RTU . However, the mortality rate for 15% Remedy + 85% water was lower (Figure 1). Bovey and Whisenant (1991) discovered that by adding Triclopyr to diesel increased mortality rate to 100%. However, when using diesel oil and water at a 1:4 ratio with Triclopyr, canopy was only reduced by 6% and a zero percent mortality rate was observed. By adding higher concentrations of Triclopyr to the diesel mixture, Bovey and Whisenant (1991) increased mortality rate by 73%. Remedy RTU consists of Triclopyr premixed with an oil carrier similar in consistency and effect as diesel. The similarities between the 2 mixtures probably contributed to the similarities in mortality rates.

MANAGEMENT IMPLICATIONS

By using either 15% Remedy + 85% diesel or Remedy RTU producers can expect to see high mesquite mortality rates. Unfortunately, Remedy RTU is no longer available; it was taken off of the market in 2006 by Dow Agrosciences.

The most economically feasible, effective control option of the three mixtures is the 15% Remedy + 85% diesel mixture. Although 15% Remedy + 85% water is substantially cheaper than the other two mixtures, it is also the least effective control option. Because mesquite trees are hard to control, when using herbicides, producers should select mixtures that will be cost effective and will result in the highest mortality rates.

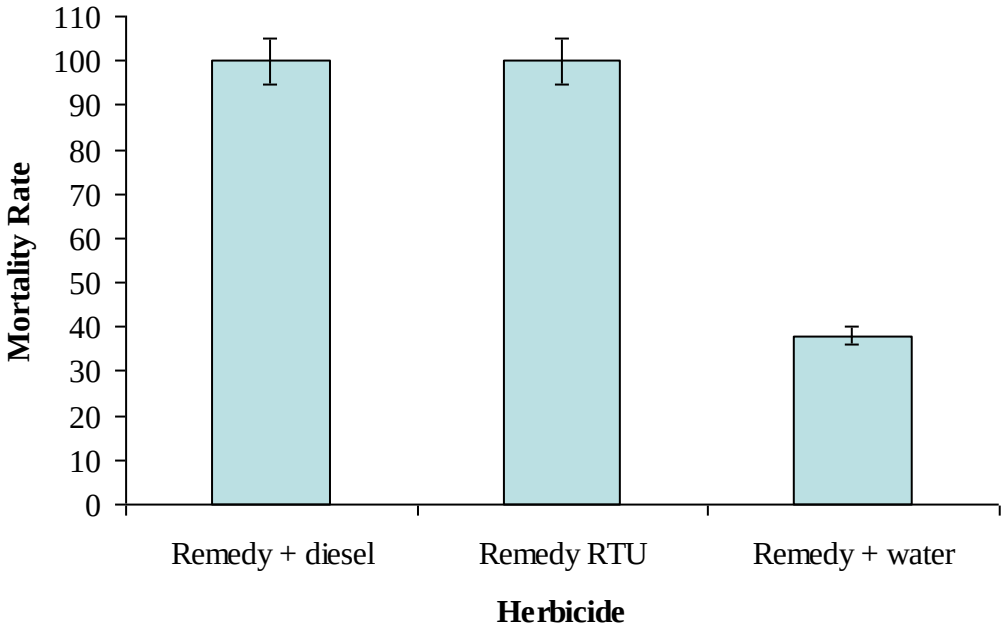

Figure 1. Mortality rates of mesquites between varying mixtures of herbicides three years after spraying using the stem spray method. Trees were basal-sprayed with 15% Remedy/85% diesel, Remedy RTU, or 15% Remedy/85% water.

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VITAMIN D SUPPLEMENTATION IN FALL BORN RAMBOUILLET LAMBS RAISED ON SMALL GRAIN PASTURES

Joe M. Self, Mike W. Salisbury, Brian J. May, Gil E. Engdahl,
Cody B. Scott and R. Horst

ABSTRACT

During preliminary data collection it was determined that lambs grazing lush small grain fields during the winter months are deficient in total vitamin D plasma concentrations. Should deficient conditions exist it could impede proper bone growth and formation. Therefore, this study was designed to determine if vitamin D supplementation shortly after birth would prevent vitamin D deficiencies in lambs grazing small grain pasture during the winter months in West-Central Texas. Forty Rambouillet lambs, born between October 15 and December 1, were blocked by sex and randomly assigned to 1 of 3 treatment groups. Treatment 1 received no vitamin D supplementation (placebo), Treatment 2 received 250,000 IU injections of vitamin D at day 14 and 42; Treatment 3 received 500,000 IU injection of vitamin D at d42. Weights and plasma vitamin D were measured at d14, 42, 68, and 90 after birth. There were no differences in weight gains, plasma vitamin D_3 or total plasma vitamin D concentrations on d14 ($P>0.05$). However, lambs supplemented on d14 had higher ($P<0.05$) total plasma vitamin d concentrations on d 42 than both the control and treatment 3 lambs. Both supplementation treatments were higher ($P<0.05$) than the control on d 68 and 90. Data suggests that supplementing with vitamin D will correct vitamin D deficiencies in fall born lambs grazing small grain fields.

INTRODUCTION

The Rambouillet breed of sheep makes up the largest portion of sheep raised in West Texas. Rambouillet sheep are suitable to West Texas environments because they are adaptable to the changing weather conditions and are heat tolerant. Typically ewes are bred so they lamb in the spring (February – May) of the year, but approximately 25% are born in the fall (October – December). When lambs are born in the spring, there is a greater abundance of forage and the nutritional management of the flock is less intensive. However, lambs born in the fall of the year require additional feed or cultivated fields usually planted with some type of small grain (wheat, rye, barley or oats), because these plants will grow when the ambient temperatures are low. A commercial producer that chooses to have lambs born in the fall is producing lambs that will be available when supplies are typically low and prices are higher. However, the majority of the lambs that are born in the fall of the year are purebred lambs that are used for seedstock and sold to commercial producers as replacement ewes and breeding rams (SID, 1996).

Ewes and lambs grazing small grain fields are consuming adequate protein and energy in their diet and when commercially available mineral supplements are provided, they consume adequate amounts of their essential minerals. However, vitamins are not normally supplemented to animals grazing lush fields because it is assumed that they

are receiving adequate amounts of vitamins to meet their nutrient requirements. A vitamin that has been ignored in most management plans is vitamin D, because it is available in all sun dried forages and is activated at the skin's surface from the sun. When considering the fact that small grains do not have any vitamin D in their plant material when it is growing, and that shortly after fall born lambs are born the day lengths are at their shortest along with the fact that young lambs are covered in wool, lambs may not be able to consume enough vitamin D or activate the required amounts at the skin's surface. In addition, during the fall and winter months in San Angelo, Texas, it is not uncommon for there to be extended periods of cloudy or overcast conditions that may last more than five days, which limits the amount of sunshine available to growing animals and compounding the problem of the lack of sunlight.

Vitamins are organic substances that are essential in small amounts for the maximum performance of animals. Vitamins must be included in the diet since they either cannot be synthesized at all or cannot be synthesized in sufficient quantities in the body (Ensminger et al., 1990). Vitamin D is required for metabolism by affecting calcium absorption, deposition, and metabolism of bone. Vitamin D promotes intestinal absorption of calcium and phosphorus and influences the process of bone mineralization (Ensminger et al., 1990). Vitamin D can be absorbed in the small intestine from the diet or can be synthesized in the skin by activation from ultraviolet light. However, sheep are poor synthesizers of vitamin D and their skin is predominantly covered with wool during most parts of the year. A deficiency of calcium and phosphorus in growing animals may result in rickets. The "bent leg syndrome" resembles a mild case of rickets with the front legs bowing out. Animals experiencing the "bent leg syndrome" are generally adequate in calcium and phosphorus ingestion and plasma levels are at normal levels, but lambs still experience the "bent leg syndrome" (Salisbury, unpublished preliminary data). Preliminary research also shows that about 33% of lambs that are raised on winter small grain fields exhibit the "bent leg syndrome," while none of the lambs raised on pasture showed the malformation of bone. Plasma vitamin D levels revealed that all fall born lambs were low in vitamin D, according to normal levels reported by Horst et al, (1982). Because of the lack of vitamin D and limited activation, coupled with increased requirements for growth, it is possible that fast growing lambs are deficient in vitamin D and thus, lacking the ability to utilize available calcium and phosphorus for proper bone development. Therefore, a study was designed to determine if strategic vitamin D supplementation could be incorporated into a management program to prevent vitamin D deficiencies in fall born Rambouillet lambs grazing small grain fields following birth.

MATERIALS AND METHODS

This study was conducted at the Angelo State University Management, Instruction, and Research Center, located in Tom Green County north of San Angelo, Texas. Forty Rambouillet lambs born October 15 – December 1 were blocked by sex and randomly assigned to one of three treatment groups at birth. Treatments consisted of a control (Treatment 1) which received only an intramuscular injection of the placebo at d 14 and d 42 of the

experiment, treatment two received an intramuscular injection of 250,000 IU of vitamin D at d 14 and d 42, and treatment three received an intramuscular injection of the placebo on d 14 and 500,000 IU of vitamin D on d 42 (Table 1). The placebo consisted of the carrier oil and preservative used to suspend the vitamin D.

All ewes were brought to the lambing facilities two weeks prior to expected parturition and allowed to lamb in confinement. At birth all lambs were identified, tails docked and vaccinated against enterotoximia and soremouth. On d 14, 42, 68, and 90 of the experiment lamb body weights were taken. On d 14 following treatment application and weighing, lambs and their mothers were taken to a small grain (oat) field where they would remain for the entirety of the experiment. The field consisted of minimal native grasses to prevent the consumption of sun cured forage that may contain vitamin D. Fresh clean water, commercial sheep mineral, and a 16% crude protein creep feed was available free choice. The mineral and creep feed did not contain any vitamin D. Lambs were inspected a minimum of three times per week for health and the incidence of the "bent leg syndrome".

On the days that body weights were taken, blood samples were also taken to measure for plasma concentrations of total vitamin D (Animal Disease Laboratory, Ames, IA). Blood samples were collected via jugular viena puncture in sodium heparin tubes. Tubes were centrifuged at 1500 x gravity and the plasma was decanted into small scintillation vials, labeled and frozen at -80^{o}C until analysis.

The first observed case of the "bent leg syndrome" was recorded on d 90 of the experiment. Therefore, d 90 became the end of the experiment because the lambs used in the trial were to be sold as replacement rams and ewes and could not be allowed to continue to deteriorate in their leg condition. At weaning, any lamb exhibiting the start of the "bent leg syndrome" was placed on a complete diet balanced to meet all NRC (1985) requirements for weaned lambs with additional vitamin D to help stop the bending of the front legs.

Statistical Analysis

Each lamb will be considered an experimental unit because treatments were applied to each individual lamb. Variables included initial (d 14), d 42, d 68 and d 90 body, body weight change, and plasma vitamin D concentrations. General linear models of SAS (SAS Inst. Inc.,Cary, NC) were used to determine treatment differences and the model included sex as a block. Means were separated using Duncan's Least Significant Difference (pdiff option in SAS) and treatments were considered different at $P \leq 0.05$.

RESULTS AND DISCUSSION

Differences in body weights or body weight gain were not found ($P > 0.05$, Table 2). These results were in contrast to those found by McDowell (1989), who reported that one of the clinical signs of rickets is decreased performance. However, these lambs were not allowed to progress beyond a mild case and probably a decreased performance would have been recognized if allowed to progress further.

No differences ($P > 0.05$) were found in vitamin D_3 concentration among treatments (Table 3). However, Horst et al. (1982) reported that vitamin D_3 is found in extremely low concentrations and

Table 1. Treatment design of fall born Rambouillet lambs receiving no vitamin D supplementation or supplemented with vitamin D on d 14 and/or d 42.

	Treatments[a]		
Day	1	2	3
d14	Inj[b], Bld, & BW	Inj, Bld, & BW	Inj, Bld, & BW
d42	Inj, Bld, & BW	Inj, Bld, & BW	Inj, Bld, & BW
d68	Bld & BW	Bld & BW	Bld & BW
d90	Bld & BW	Bld & BW	Bld & BW

[a]Treatment 1 received placebo vitamin D supplementation of d 14 and d 42, treatment 2 received 250,000 IU vitamin D supplementation on d 14 and d 42, and treatment 3 received the placebo on d 14 and 500,000 IU vitamin D supplementation on d 42.
[b]Inj = injection, either placebo or vitamin D; Bld = blood sample taken; BW = body weight taken.

Table 2. Body weights and gain in fall born Rambouillet lambs receiving no vitamin D supplementation or supplemented with vitamin D on d 14 and/or d 42.

	Treatments[a]			
Days	1	2	3	SE[b]
d 14, initial	8.91	9.42	9.41	0.544
d 42	17.40	18.44	18.86	0.882
d 68	26.91	28.59	28.82	1.150
d 90, weaning	37.05	38.97	39.32	1.282
Weight gain	28.14	29.55	29.90	0.882

[a]Treatment 1 received placebo vitamin D supplementation of d 14 and d 42, treatment 2 received 250,000 IU vitamin D supplementation on d 14 and d 42, and treatment 3 received the placebo on d 14 and 500,000 IU vitamin D supplementation on d 42.
[b]SE = most conservative standard error of the least squares mean.

Table 3. Plasma concentration of vitamin D (pg/ml) in fall born Rambouillet lambs receiving no vitamin D supplementation or supplemented with vitamin D on d 14 and/or d 42.

	Treatment[a]			
Item	1	2	3	SE[b]
D_3	76.3	63.2	63.9	4.86

[a]Treatment 1 received placebo vitamin D supplementation of d 14 and d 42, treatment 2 received 250,000 IU vitamin D supplementation on d 14 and d 42, and treatment 3 received the placebo on d 14 and 500,000 IU vitamin D supplementation on d 42.
[b]SE = most conservative standard error of the least squares mean.

differences are difficult to detect. Therefore, differences were not expected.

However, when D_2 and D_3 were measured together as total vitamin D differences are easier to detect. In the initial (d 14) blood samples, concentrations were similar ($P > 0.05$, Table 4), which was expected since Bonniwell et al. (1988) reported that lambs are born with adequate levels of vitamin D until they are six weeks of age. Yet, at d 42 the lambs receiving 250,000 IU of vitamin D at d 14 were higher ($P < 0.05$) in plasma vitamin D concentration, but even the lambs not receiving vitamin D supplementation were still at normal (21.1 ng/ml) levels. Since d 42 is at six weeks of age, lambs not receiving any supplement would not be expected to be deficient yet. Nonetheless, on d 68, lambs not receiving vitamin D were lowest ($P < 0.05$) in plasma concentrations and their levels were below normal levels according to that reported by Horst et al. (1982). The differences ($P < 0.05$) remained the same for d 90, where the nonsupplemented lambs were below normal and those lambs receiving vitamin D were well above normal levels.

Treatment 2 received supplementation on both d 14 and d 42 and their levels remained fairly constant throughout the trial, but treatment 3 received supplementation only on d 42 and their concentration made a dramatic increase following supplementation. Additionally, treatment 3 lambs were only slightly above normal levels when they received their large dose of vitamin D at d 42, which was followed by the spike in concentrations. Should supplementation occur at an earlier age, levels just above normal may not have ever occurred and their concentrations may have been more even as seen in treatment 2.

The incidence of the "bent leg syndrome" was only used to determine the time at which the lambs should be weaned. Therefore, differences were impossible to detect and data were not analyzed, because it was impossible to determine how many would actually exhibit the condition. Should the lambs have been allowed to progress further, there may have been an observable difference in the condition.

CONCLUSIONS

It appears that supplementing lambs with vitamin D will prevent deficiencies either supplemented with one-half a dose at d14 and 42 or supplemented with the entire dose at d42. Therefore, the data suggests that a vitamin D deficiency is present in fall born lambs grazing small grain fields, and supplementation will correct the deficiency.

Table 4. Plasma concentration of total vitamin D (D_2 and D_3) concentrations (ng/ml) in fall born Rambouillet lambs receiving no vitamin D supplementation or supplemented with vitamin D on d 14 and/or d 42.

	Treatment[a]			
Days	1	2	3	SE[b]
14 d	36.0[a]	28.3[a]	29.2[a]	5.17
42 d	23.6[a]	79.1[b]	22.2[a]	5.17
68 d	17.9[a]	92.2[b]	101.1[b]	5.17
90 d	16.1[a]	77.9[b]	75.4[b]	5.17

[a]Treatment 1 received placebo vitamin D supplementation of d 14 and d 42, treatment 2 received 250,000 IU vitamin D supplementation on d 14 and d 42, and treatment 3 received the placebo on d 14 and 500,000 IU vitamin D supplementation on d 42.
[b]SE = most conservative standard error of the least squares mean.

There is however, a critical time between day 14 and day 42 that should be examined more closely to determine the most appropriate time to give single massive dose injections. Treatment 3 had two lambs that exhibited the "bent leg syndrome", and this could be because the lambs were deficient prior to the time at which they received their supplementation and the supplementation occurred too late.

It appears from the data that the deficiency can be corrected by supplementation, but the correct timing of supplementation is not thoroughly understood. Other researchers have reported that lambs are born with enough vitamin D to last six weeks, but should supplementation occur at the six week point as in treatment 3 of the current study, or a few days earlier? Treatment 2 had a more even concentration of vitamin D, but could the supplementation have been postponed to accommodate a single supplementation time for easier management practices?

In the current study, lambs were not allowed to progress to a point where the "bent leg syndrome" was visible. replacement rams and ewes develop the "bent leg syndrome".

Deficiency were corrected in the lambs by supplementing vitamin D, but it was inconclusive as to whether the supplementation prevented the "bent leg syndrome." Therefore, additional work needs to be done to determine if the current levels of supplementation would actually prevent the condition. Furthermore, is the critical timing of supplementation necessary in preventing deficiencies which could lead to the onset of the "bent leg syndrome?"

Once the correct level of supplementation has been determined it must be investigated to determine which mode of administering a vitamin D supplement is the most efficient and easiest to administer. Ideally, a feed or mineral supplement with vitamin D could be developed to provide the appropriate level to young growing lambs that are grazing small grain pastures.

Since small grain pastures are an efficient and easy way to manage fall born lambs, it is vital that research determine a method to prevent the "bent leg syndrome" and reduce the economic loss purebred producers incur when potential

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EFFECT OF COPPER SUPPLEMENTATION ON ARTIFICIAL INSEMENATION CONCEPTION RATE OF ANGUS COWS AND FEEDLOT PERFORMANCE OF ANGUS BULLS

Ned A. Dunbar, Brian J. May, Micheal W. Salisbury, Cody B. Scott, and M. Todd Schafer

ABSTRACT

Copper (Cu) oxide boluses were administered in two trials to evaluate their effects on Artificial Insemination (AI) conception rates in Angus cows and heifers and feedlot performance in Angus bulls. Blood plasma samples were taken and evaluated in both trials. Trial 1; 68 Black Angus cows ranging from 1-12 y of age were randomly assigned to one of three treatment groups (Trt); Trt 1) Control, Trt 2) 1 Cu bolus on d 180, Trt 3) 2 Cu boluses, d 0 and d 180. There were no differences ($P > 0.05$) in conception rates among treatments. Copper supplementation resulted in heavier ($P < 0.05$) birth weights than in unsupplemented cows. Trial 2; 20 yearling Angus bulls were randomly assigned to one of two Trt; Trt 1) Control, Trt 2) Cu bolus on d 0. Treatment 2 had a higher ($P < 0.01$) average daily gain (ADG) than Trt 1. Results show that Cu did not increase conception but may increase birth weights in fetuses and ADG in fed Angus bulls.

INTRODUCTION

In order to optimize performance in livestock, nutritional balance must occur. Deficiency of various trace minerals can hinder performance and prevent the animal from reaching its optimum potential. Balanced nutrition is especially important in reproduction whether it is by natural mating or by artificial insemination (AI) (Field and Taylor, 2003).

Copper (Cu) deficiency is a widespread problem in cattle (Suttle, 1986; McDowell, 1992) and can be caused by low intake of Cu levels or high intake of Molybdenum (Mo) and Sulfur (S) (Ward and Spears, 1999). Concentrations of S and Mo are the major dietary factors influencing copper requirements (NRC, 1985) because S and Mo form physiological complexes that tie up Cu and render it nutritionally unavailable to animals. This kind of situation can occur in pastureland where there is a deficiency in dietary Cu and thus, require supplementation in order to maximize performance.

It is common to see livestock operations in west Texas have sheep and cattle together under range conditions. Sheep are more susceptible to Cu toxicity than cattle (Maynard et al., 1979). In fact, if the Mo level is low, forage with a normal Cu content of 8 to 11 ppm can produce toxicity in sheep (NRC, 1985). The requirement for beef cattle is 10 ppm in their diet to supply their daily requirement (NRC, 1996). Research has shown that in cattle grazing pastures containing 3 to 20 ppm Mo, Cu concentrations in the range of 7 to 14 ppm were inadequate. Therefore, inadequate levels of dietary Cu in cattle can be toxic to sheep under some conditions. Some manufactured supplements contain 25 to 35 ppm Cu which is well above the recommended maintenance requirement for adult of 4.6 to 7.4 ppm Cu (NRC, 1985). A supplementation dilemma occurs when trying to adequately

supplement cattle and not subject the sheep to Cu toxicity.

Supplemental Cu can be beneficial in performance of feedlot cattle (Ward and Spears, 1999). Research has shown that ADG tended (P=0.11) to increase with Cu supplementation compared with the unsupplemented control (Arthington et al., 2003). Other studies have shown that gestating cattle may need greater amounts of Cu to ensure adequate Cu stores in the livers of their offspring (Ward et al., 1995) and that supplementation improves AI pregnancy rate (Ahola et al., 2004).

In order to further understand the role that Cu plays on reproduction in beef cattle and performance in fed cattle, more research is needed.

MATERIALS AND METHODS

Animal Management

Trial 1 was conducted at the Angelo State University Ranch north of San Angelo, Texas on Highway 87. Black Angus cows ranging in age from one year of age to 12 years of age were assigned to one of three Cu supplementation treatments. Cows were blocked by age and the blocks were multiparous cows (3-12 years of age), single-parous cows (2 years of age), and heifers (1 year of age). Cows were randomly assigned to 3 treatments with equal numbers of each age group in each treatment.

Treatments were as follows; treatment 1—Control (no Cu supplement), treatment 2—1 capsule of supplemental Cu, treatment 3—2 capsules of supplementation. Treatment 2 received their dose on d 180 of the study and Treatment 3 received a dose on d 0 and d 180. The supplemental dose is a 25g Cu bolus (Animax; Stanton, England). Each bolus contains 100s of tiny Cu oxide wires in a gelatin capsule. Once in the rumen, the gelatin capsule dissolves allowing the Cu wires to disperse throughout the digestive tract and dissolve slowly over a time giving a constant flow of Cu to the animal. The bolus was deposited into the rumen via "Balling Gun."

All three treatments were placed together to prevent treatment x location interactions. The cattle were placed together on pastureland and either wheat or oat fields. They were fed mineral free choice, which does not contain Cu, in order to meet other nutrient requirements. Forage samples were taken in the fields and the pastures and were analyzed by Dairy One Forage Laboratory for Cu content (Dairy One; Ithaca, New York).

Blood samples on the cattle were also taken. The blood samples were collected on days 0, 7, 14, 28, 56, and at 56-day intervals after day 56. The blood was collected via caudal veinapuncture into heparinized blood collection tubes. The tubes were transported on ice to the Angelo State University Management, Instruction, and Research Center to be centrifuged at 2500 rpm for 30 minutes at 5˚C immediately following bleeding. Plasma was separated into collection vials, frozen, and stored. Blood plasma samples were shipped frozen for analysis to CEPS Central Analytical Laboratory (University of Arkansas Poultry Science Center; Fayetteville, AR)

All treatments received an intramusclar shot of PGF2α (ProstaMate, St. Joseph, MO) for estrus synchronization. Estrus was synchronized using the two shot method described by Wilson (2000). Heat watch patches were mounted just above the tail head for mount detection and estrus determination. Approximately 8-12 hours after estrus, each cow was artificially inseminated. Cows were then exposed to a bull the

following estrus cycle as a backup to the artificial insemination. Conception rates on all three treatments were assessed. Birth weights were recorded and assessed on the offspring of the treatments to see the effect that Cu supplementation has on the growing fetus.

Trial 2 was conducted using 18 Angus bulls on full feed. They were randomly selected into two treatment groups. Treatment 1 received the supplementation and treatment 2 did not (Control). Blood samples were collected at the same time and by the same method as the cows in Trial 1. Weight gain and ADG were recorded.

Statistical Analysis

The experimental design is a randomized complete block with parity serving as the block. Individual cow or bull served as an experimental unit. Single point data (wt gain, calf birth weights, weaning weights and average daily gain) were analyzed using the general linear models (GLM) of SAS (SAS Institute, Cary NC). Conception rates were analyzed with Chi-square and plasma Cu concentrations were analyzed as a repeated measures. Treatments were considered different at $P \leq 0.05$.

RESULTS and DISCUSSION

Forage Analysis

Forage samples that were analyzed for dietary Cu content showed no differences in levels of Cu in any of the pastures that the cattle were exposed to during the study. The forage samples had Cu levels ranging from 9-11 ppm (Table 1). The current NRC (1996) recommendations for dietary copper levels in cattle recommend 10 ppm in the total consumed feed.

Trial 1

None of the blood plasma Cu levels analyzed were below 0.85 ppm, which is above the 0.60 ppm that indicates Cu deficiency in beef cattle (NRC, 1996). There were no plasma Cu level differences among treatments in this study (Table 2). However, there was a difference in plasma Cu levels among age. Heifer calves had lower Cu plasma concentrations ($P < 0.05$; Table 3) than both first-calf heifers and cows regardless of treatment. This may be indicative of higher Cu maintenance requirements for growing heifer calves than older cattle. The latest edition of the Nutrient Requirements for Beef Cattle by the NRC (1996), states that growing pregnant heifers require higher levels of energy, protein, and minerals such as calcium (Ca) and phosphorus (P). Though not mentioned in the requirements, there could be a higher requirement for Cu in growing pregnant heifers as well, but this increase may not be substantial enough to make a physiological difference. Providing nutrients to meet animal requirements is especially important when pushing young females into reproductive productivity and maintaining reproductive efficiency in older females (NRC, 1996).

Cows and heifers were given a numbers upon parturition associating when she conceived and then analyzed by treatment groups and by age. If they conceived by first service AI they were given a 1, second service AI a 2, cleanup bull a 3, and if they never came into drug induced estrus a 4. When calving data was analyzed by treatment, there were no differences. The percentage of cattle conceiving either first or second service AI were 82% in treatment 1, 84% in

Table 1: Dietary copper content of forage samples collected in fields and pastures at the Angelo State University Ranch

Pastures	Cu[a]
1[b]	10
2[b]	9
3[b]	9
4[c]	9
5[d]	11
6[d]	11

[a] Copper values in column are expressed as ppm
[b] Grass pasture land
[c] Oat field
[d] Wheat fields

Table 2: Plasma copper levels (ppm) in Angus cows and heifers receiving no copper supplementation or supplementation using a continuous release copper bolus

	Treatments[a]			
	1	2	3	*SE*[b]
Bleeding 1 d 0	1.25	1.05	1.11	0.060
Bleeding 2 d 7	1.18	1.13	1.23	0.061
Bleeding 3 d 180	1.08	1.10	1.29	0.078
Bleeding 4 d 236	1.13	1.12	1.19	0.047

[a] Treatments = 1 Control; 2 bolus on d 180, 3 bolus on d 0 and d 180
[b] SE = Standard error of the least squares mean

Table 3: Plasma copper (ppm) levels in Angus cows and heifers regardless of copper supplementation

	Age[a]			
	HC	H	C	SE[b]
Bleeding 1, d 0	1.12[cd]	1.27[d]	1.03[c]	0.055
Bleeding 2, d 7	1.25[c]	1.24[c]	1.05[d]	0.049
Bleeding 3, d 180	1.14[c]	1.33[d]	0.99[c]	0.063
Bleeding 4, d 236	1.05[c]	1.23[d]	1.15[d]	0.037

[a] HC = heifer calves; H = heifers (single-parous cows); C = cows (multiparous cows)
[b] SE = Standard error of the least squares mean
[cd] Means in the same row with differing superscripts are different ($P < 0.05$)

treatment 2, and 89% in treatment 3. Treatment 3 had the highest percentage of cattle that conceived AI however; it was not different than the other two treatments. These data support previous research by Muehlenbein et al. (2001), where no effect of Cu supplementation on 60-d pregnancy rates was observed when compared to unsupplemented cows. Previous research by Olson et al. (1999) showed negatve effects of Cu (trace mineral) supplementation on pregnancy rate observed in 2-yr old beef cows. These findings are different when compared to a study conducted by Ahola et al. (2004) where they found that Cu supplementation improved pregnancy rate to AI compared with cows not supplemented. Also in contrast to the results of this experiment, Stanton et al. (2000) reported a greater pregnancy rate to mass insemination in cows supplemented with Cu (trace minerals) than in cows not supplemented. However, based on liver Cu concentrations reported by Stanton et al. (2000), cows appeared to be deficient in Cu, whereas the cattle in this experiment did not show defficient levels of Cu in plasma concentrations. This could be a factor in why no supplemental differences in conception rates were shown in this study.

When calving data was analyzed by age, heifer calves as an age group regardless of treatment had lower conception rates ($P < 0.05$). This may not be relevant to Cu levels. First of all, with heifers, it is not known if the animal is even reproductively sound because there has not been an opportunity previous to this study proving that she is capable of reproducing. Second, one animal may not sexually mature as fast as another, therefore, she may not conceive as quickly as other cattle. Age of puberty differs among breeds of cattle as well as females within the same breed (NRC, 1996). The onset of puberty can also be affected by weight and low body condition score (Field and Taylor, 2003). Underfeeding as well as deficiency in some minerals can delay puberty in heifers (NRC, 1996).

Birth weights of the calves were recorded and compared among treatments (Table 4). Birth weights of calves in treatment 3 were higher than in treatment 1 ($P = 0.0013$) and in treatment 2 as well. Copper concentrations of 170d old calves of cattle fed Cu supplemented diet were higher ($P < 0.05$) than calves of cattle fed non-Cu-supplemented diets (Gengelbach et al., 1994). Ward et al. (1995) stated that gestating cattle may need greater amounts of copper to ensure adequate copper stores in the livers of their offspring. This indicates that substantial Cu stores in the livers of gestating cows also provides substantial Cu stores in the livers of their offspring which can be beneficial to growth performance in their offspring. Ward et al. (1997) showed that Cu supplementation increased dry matter intake (DMI) during the receiving and growing phases and increased ADG and gain: feed ratios during the finishing phase. In a study that evaluated the effect of Cu bolus administration before weaning (Arthington et al., 1995), weaning weights were heavier in bull calves and tended to be heavier in heifer calves that received supplemental Cu compared with unsupplemented controls. These studies by Ward et al. (1997) and Arthington et al. (1995) indicate that Cu supplementation has a physiological effect on growth. If Cu supplementation increases growth rate and Cu supplementation in gestating females increases the amount of Cu in their offspring, it is easy to see how Cu supplementation can increase birth

Table 4: Mean birth weights in Angus cows and heifers receiving no copper supplementation or supplementation using a continuous release copper bolus

	Treatments[a]			
	1	2	3	SE[c]
Birth Weights[b]	35.76 [d]	37.98 [d]	41.43 [e]	1.24

[a] Treatments = 1 Control; 2 bolus on d 180, 3 bolus on d 0 and d 180
[b] Average Birth Weights expressed in kg
[c] SE = Most conservative standard error of the least squares mean
[de] = means in the same row with differing superscripts are different ($P < 0.05$)

weights in calves whose dams were supplemented with Cu. Although not originally hypothesized in this study, this finding could be very important and should be considered before producers supplement pregnant cattle with Cu. Increasing birth weights of calves in Cu supplemented dams could cause dystocia problems (trouble giving birth), especially in smaller cows and heifers that are susceptible to this condition.

Trial 2

Blood results in Trial 2 were much like the ones in Trial 1. There were no differences in Cu plasma levels between supplemented and nonsupplemented bulls ($P > 0.05$; Table 5). There was a significant difference of amount of total gain ($P < 0.0001$) and ADG ($P < 0.0001$) between supplemented and nonsupplemented bulls (Table 6). Ward et al. (1997) showed that Cu supplementation increased DMI during the receiving and growing phases and increased ADG and gain: feed ratios during the finishing phase. Heifer ADG tended ($P = 0.11$) to increase with Cu supplementation compared with the unsupplemented control in another study (Arthington et al., 2003). Arthington et al. (1995) found that Cu bolus supplemented weaned bulls had heavier weaning weights than controls when supplemented before weaning. Also, Cu supplementation at 10 or 40 mg/kg of DM improved ADG and daily feed intake (Engle et al., 2000). Conversely, Engle and Spears (2000) indicate that as little as 20mg/kg of supplemental Cu can reduce performance in finishing steers. Gengelbach et al. (1994) and Muehlenbein et al. (2001) found no significant differences in body weight changes for first-calf heifers exposed to mineral treatments. Interestingly, most literature that has findings in contrast to the findings of this study was trials that added dietary Cu supplementation to a feed ration. Adding dietary supplements to a feed ration can have negative effects on palatability. If the dietary additive decreases palatability then there would be a decrease in DMI, feed: gain ratio, and ADG. In this study, bulls were supplemented will a Cu oxide bolus that gives a continual and steady release of Cu for an extended period of time, thus having no negative effects on palatability.

Table 5: Plasma copper levels (ppm) in weaned Angus bulls receiving no copper supplementation or 1 copper continuous release bolus

	Treatments[a]		
	1	2	SE[b]
Bleeding 1	0.94	1.16	0.083
Bleeding 2	1.19	1.10	0.197
Bleeding 3	1.03	1.09	0.023
Bleeding 4	1.45	1.14	0.207

[a] treatment 1 = copper continuous release bolus on d 0; treatment 2 = no copper bolus

[b] SE = standard error of the least squares mean

Table 6: Body weight and body weight gains in Angus bulls either receiving or not receiving copper bolus supplementation

	Treatments[a]		
	1	2	SE[b]
Initial wgt, kg	365.15	311.52	11.32
Final wgt, kg	579.04	484.39	15.36
Gain	213.89[d]	172.88[c]	5.25
ADG	1.81[d]	1.46[c]	0.04

[a] treatment 1 = copper continuous release bolus on d 0; treatment 2 = no copper bolus

[b] SE = standard error of the least squares mean

[cd] Means in the same row with differing superscripts are different ($P < 0.05$)

IMPLICATIONS

Cows and heifers supplemented with Cu boluses showed higher percentages of first or second service AI conception rates but did not show any statistical differences between treatments. Copper bolus supplementation in gestating cows and heifers can increase birth weights in their calves at parturition. Careful consideration should be used when deciding to use Cu boluses in gestating first-calf heifers due to the risk of dystocia. Copper bolus supplementation in fed cattle can improve ADG and growth rate. Additional research is needed to determine effects on feed: gain ratio.

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THE EFFECT OF PROTEIN LEVEL ON FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF TEXAS RAMBOUILLET EWES

Norberto Mendoza Jr., Brian J. May, Michael W. Salisbury, and Gil R. Engdahl

ABSTRACT

Twenty-seven Rambouillet ewes with a mean body weight of 53 kg were used to determine the effect of protein level on feedlot performance and carcass characteristics of slaughter ewes. The ewes, blocked by weight and body condition score (BCS), were randomly assigned to one of three treatments; wheat hay (WH), soybean hulls (SBH), and a balanced grain ration (GR), which contained varying protein concentrations. Feed and water were offered *ad libitum* and feed refusals were weighed back. Ewes were weighed every 28 days and harvested on day 84. Differences ($P<0.05$) were found for total gain, average daily gain (ADG), fat deposition, and feed efficiency when GR was compared to WH and SBH, as well as differences ($P<0.05$) in BCS, and change in BCS when SBH and GR were compared to WH, and in intake among all treatments. No differences were found for final weight, hot carcass weight, or dressing percent. Economically, no differences were found; all treatments were unprofitable.

INTRODUCTION

Sheep production in West Central Texas is a large constituent of the agricultural economy of the area. The West Texas region is considered the top sheep producing region in the nation (USDA-AMS, 1997). According to the United States Department of Agriculture – National Agriculture Statistics Service (USDA-NASS), the West Central region of Texas had an inventory of 857,000 head of sheep in 2003. This comprises 76 percent of all sheep in Texas (USDA-NASS, 2003). In 1997 sheep, lamb, and wool sales totaled 97 million dollars in Texas. Most of this was from the sale of red meat, especially that of lambs. Yet, a part of this red meat also comes from the sale of older ewes.

The termination of wool subsidies made sheep producers turn their focus from wool production to red meat production. Sheep operations in West Central Texas make most of their money from the sale of feeder lambs to feedlots (Personal communication, A.H. Denis, Denis Ranch, Vancourt, TX). On a per farm basis, there is a thin margin between profit and loss on sheep operations. Therefore, any extra income to a sheep producer from any venue, such as sales of cull ewes fed to a higher weight, can be the difference between profit and loss.

Aged ewes, 5 to 7 years old, are usually ewes that the producer has decided not to breed anymore. The ewes are usually sent to harvest facilities after their last lamb is weaned, as an effort to minimize the cost of maintenance for the operation. Some producers have chosen to feed their aged ewes high energy diets, a feedlot practice, before they send them to harvest. This practice may prove to be profitable as the ewes will gain extra weight and

Research on the feedlot performance of aged ewes is very limited. Therefore, little is known about how aged

ewes perform in feedlot situations. The purpose of this research is to compare protein level on feedlot performance (rate and efficiency of gain) and carcass composition in aged Rambouillet ewes.

MATERIALS AND METHODS

Animals and Feeding

This study was conducted at the Angelo State University Management, Instruction, and Research Center (MIR Center), located in Tom Green County north of San Angelo, Texas. A total of 28 Rambouillet ewes averaging 53 kg were used for this trial. The ewes were blocked by weight and BCS and assigned to 14 pens of two ewes per pen. Pens were allocated to one of the three different treatments consisting of four pens on WH, five pens on SBH, and five pens on GR, which was prepared at the MIR Center, (Table 1) containing varying levels of protein. All treatments met or exceeded NRC requirement for maintenance in ewes (NRC, 1985a). Ewes had *ad libitum* access to feed and fresh water for the 84d trial. Feed refusals were removed and weighed each time a new batch of feed was placed in the feeders so that feed efficiency could be calculated, including ADG, gain:feed ratio, cost of gain, and profit. Feed efficiency was calculated by dividing the kg of gain by kg of feed. Percent of maintenance CP and percent of maintenance TDN were calculated for each diet. Ewes were kept in pens measuring 3.048 m by 9.144 m. Upon arrival ewes were tagged and weighed and treated with an anthelmintic.

Data Collection

Ewes were individually weighed on day zero, to get the initial weight, 28, 56, and 84, for final weight, to determine feedlot performance for each treatment. At initial and final weigh days, ewes were evaluated and given a BCS on a scale of zero to five, zero being extremely emaciated and five being excessively obese. Evaluation was done by palpation method as described in the Sheep Production Handbook (American Sheep Industry Association, 1996). At d 84 of the trial, ewes were harvested following normal commercial conditions at Rancher's Lamb of Texas Inc., and carcasses were spray chilled at 2^{o}C for 20 to 24 hours. Carcasses were then evaluated for backfat thickness at the twelfth rib. Dressing percent was also calculated by taking the hot carcass weight (HCW) and dividing it by the live weight and multiplying it by 100.

Statistical Analysis

The trial was a completely randomized block design with a pen of two ewes being the experimental unit. The General Linear Model procedure (SAS Inst. Inc., Cary, NC) was used to determine the effect of protein level on feedlot performance and carcass characteristics. Analysis of variance and Fisher's protected LSD test was used to determine statistical significance at a predetermined $\alpha = 0.05$.

RESULTS AND DISCUSSION

Feed Analysis

Chemical analysis of all three feed treatments was conducted by Dairy One Inc., Ithaca, NY. Although the CP levels in SBH were lower than WH, TDN values were different with WH being the lowest followed by SBH and then GR. Table 2 shows the percent of maintenance CP and TDN which the ewes ingested for each treatment. Maintenance CP and TDN levels were obtained from the NRC (1985a).

Table 1. Ingredients and nutrient density for WH, SBH, and GR fed *ad libitum* for 84 d.

	Treatment[a]		
Item	WH	SBH	GR
	----------% as fed----------		
Ingredients			
Sorghum grain	-	-	45
Soybean hulls	-	100	22.5
Alfalfa pellets	-	-	17
Cottonseed meal	-	-	10
Cane molasses	-	-	3
Mineral premix	-	-	2.5
Wheat hay	100	-	-
	----------DM----------		
Nutrient Density			
Crude Protein(CP), %	15.4	14.3	17
NE_g, Mcal/kg	0.6	0.7	1.2
Neutral Detergent Fiber, %	51.4	59.8	34.3
Acid Detergent Fiber, %	28.7	40.2	25.7
TDN, %	59	63	76

[a]WH = wheat hay, SBH = soybean hulls, GR = grain ration

Table 2. Percent of maintenance crude protein and total digestible nutrients which pens of Texas Rambouillet ewes were ingesting per treatment.

	Treatment[a]		
Item	WH	SBH	GR
n	4	5	5
% of maintenance CP	166	258	405
% of maintenance TDN	109	195	311

[a]WH = wheat hay, SBH = soybean hulls, GR = grain ration

Performance Data

Ewes were blocked by weight and initial BCS. No differences ($P>0.05$) were found for weight and initial BCS (Table 3). The total number of ewes on trial was 28 in 14 different pens. The 14 pens were four pens on WH, five pens on SBH, and five pens on GR. Table 3 shows the least square means of final body weight (BW), gain, ADG, final BCS, and BCS change. No differences ($P>0.05$) were observed for the mean final weights. Although the ewes on GR gained more than the other treatments, they averaged a lighter initial weight numerically, therefore, the final weights tended to average to the same weight. Both total gain and ADG were significantly higher ($P<0.05$) for GR when compared to WH and SBH. Ewes on GR increased an average of 19.7 kg, which was 15 kg and 10.6 kg more than WH and SBH, respectively. This result agrees with Fluharty and McClure (1997), Hinds et al. (1965), and Hudson et al. (1967) who found increases in ADG and final weight in growing lambs when they increased the

Table 3. Least square means of initial weight and BCS, and the effect of protein level on feedlot performance of pens (two ewes/pen) of Texas Rambouillet ewes.

	Treatment[a]			
Item	WH	SBH	GR	SE[b]
n	4	5	5	
Initial wt (kg)	113	108	100.2	6.8
Initial BCS(avg/animal)	2.25	1.97	1.96	0.17
Final BW, kg	122.4	126.2	139.8	8.5
Total Gain, kg	9.4[c]	18.22[c]	39.4[d]	4.5
ADG. kg/d	0.1[c]	0.22[c]	0.46[d]	0.06
Final BCS(avg/animal)	1.72[c]	2.83[d]	3.28[d]	0.18
BCS change(avg/animal)	0.53[c]	0.85[d]	1.31[d]	0.21

[a]WH = wheat hay, SBH = soybean hulls, GR = grain ration.
[b]Standard error of estimate.
[c,d]Means in the same row with uncommon superscripts differ $P < 0.05$.different ($P<0.05$) for SBH and GR from WH.

recommended NRC protein requirement. The final BCS and BCS change were also Table 4 displays the intake and feed efficiency least square means for the three treatments. All three treatments significantly differed ($P<0.05$) from each other in intake. A difference in intake greatly differed between WH and GR from 199.6 to 393.2 kg per pen, respectively, a difference of 193.6 kg. A significant difference ($P<0.05$) was seen in efficiency when GR was compared to WH and SBH. GR ewes gained 0.10 kg per kg of feed consumed, while WH and SBH ewes only gained 0.03 kg and 0.06 kg, respectively, per kg of feed consumed. Fluharty and McClure (1997) also found an increase ($P<0.01$) in dry matter intake, but observed no difference in feed efficiency when protein level was increased in lamb rations. In another study, done by Braman et al. (1973), lambs and steers fed protein supplements had significantly higher feed efficiencies. Lana et al. (1997) observed no improvement in ADG or feed efficiency. The effects of protein increases in a ration are greatest when a ration is low in protein and another is high in protein and energy is readily available (Zinn and Owens, 1993). Small increments in protein make very little difference.

Carcass Data

In this study fat depth, at the twelfth rib, hot carcass weight, and dressing percent were observed (Table 5). The fat depth of GR ewes was significantly different ($P<0.05$) from that of SBH and WH. WH and SBH fat depth measurements were not significantly different ($P>0.05$), but tended to increase as protein level increased. No differences ($P>0.05$) were found in hot carcass weight and dressing percent measurements, only a tendency for weight to increase as protein level increased. Overall protein had only a slight effect on carcass composition other than fat depth. This agrees with findings of Braman et al. (1973) on steers and lambs and Prior et al. (1977) with cattle.

Economic Data

Table 4. Least square means of intake, feed efficiency, and the effect of protein level on carcass characteristics of pens (two ewes/pen) of Texas Rambouillet ewes.

	Treatment[a]			
Item	WH	SBH	GR	SE[b]
n	4	5	5	
Intake, kg	199.6[e]	308[f]	393.2[g]	31.6
Efficiency, kg gain/kg feed	0.03[e]	0.06[e]	0.10[f]	0.015
Fat depth[c]. cm	0.45[e]	0.57[e]	1.07[f]	0.05
Hot carcass weight, kg	52.2	55.5	61.9	4.3
Dressing percent[d]	42.8	44.9	48.0	2.21

[a]WH = wheat hay, SBH = soybean hulls, GR = grain ration.
[b]Standard error of estimate.
[c]Fat depth measurement at the twelfth rib (avg/animal).
[d]Dressing percent = hot carcass weight/live weight.
[e,f,g]Means in the same row with uncommon superscripts differ $P < 0.05$.

Table 5. Analysis of treatment cost.

	Treatment[a]		
Item	WH	SBH	GR
Price per 909.1 kg	$70.00	$106.00	$131.94
Price per kg	$ 0.08	$ 0.12	$ 0.14

[a]WH = wheat hay, SBH = soybean hulls, GR = grain ration.

Table 5 shows the cost of the WH, SBH, and GR feeds. The average price of WH was $70 per 909.1 kg (USDA-NASS, 2003) which equated to $0.08 per kg. The prices for SBH and GR were obtained from the financial records of the MIR Center and calculated to $0.12 and $0.14 per kg, respectively. The highest protein, GR, was $61.94 per 909.1 kg more than lowest protein WH.

Table 6 shows the least square means of the economic data for this trial. Ewes were sold at the harvest facility for $0.55 kg of carcass weight. No differences ($P>0.05$) were found between any of the treatments for carcass value. Total feed cost, cost of gain, and profit were not statistically tested, only calculated on averages. Table 6 shows that all treatments were at a loss. Yet, since the smallest cost of gain is $1.70, and the ewes only bring $0.55 kg, this seems to imply that feeding out aged ewes is non-profitable. However, at the time these ewes were bought the price of slaughter ewes was high because supply was low, and when ewes were sold prices were low. The average price per slaughter ewe is $0.66 per kg or $33.00 for a 50 kg ewe. If the market had remained steady from purchase to sale the profit margin would have been positive.

IMPLICATIONS

Results from this trial show increased gain rates in aged ewes and more weight on the higher protein treatment. In addition, the fat depth at the twelfth rib increases with increasing protein level. Overall, this trial showed a loss of money occurs when feeding out aged ewes; however, if market conditions remain steady the cost of gain should be profitable. Further research is needed to determine the actual profitability of feeding aged ewes on an actual operation situation where the operator does not have to purchase the ewes.

SUMMARY

Feedlot performance and carcass traits of Texas Rambouillet ewes on treatments with different levels of protein were compared. A total of 28 ewes were blocked by weight and BCS and randomly assigned to a pen. The pens measured 3.048 m by 9.144 m. Ewes were placed in one of 14 pens with two ewes per pen. Pens were allocated to one of three different treatments consisting of WH, SBH, and GR. These treatments resulted in varying amounts of protein. Ewes were weighed every 28 days and kept on trial for 84 days. Carcass characteristics were measured after carcasses were chilled for 24 hours.

The trial consisted of 28 ewes in 14 different pens, four pens on WH, five pens on SBH, and five pens on GR. Performance was greater ($P<0.05$) for ewes on GR for total gain, ADG as well as BCS and BCS change. Feed efficiency was also better ($P<0.05$) for GR as compared to WH and SBH. Ewes on GR had greater ($P<0.05$) fat depth at the twelfth rib than SBH or WH and SBH ewes were fatter than WH with no differences ($P>0.05$) across treatments in carcass weights or dressing percents.

Upon evaluation of the economic data, the feeding of aged ewes in a down market appears to be unprofitable and actually resulted in a loss. However, if the market remained steady, profit could be gained by feeding aged ewes. This only shows that further focus of commercial operations is needed to determine the actual profitability of feeding aged ewes.

Table 6. Least square means of economic data (U.S. dollars) for pens (two ewes/pen) of Texas Rambouillet ewes.

	Treatment[a]			
Item	WH	SBH	GR	SE[b]
n	4	5	5	
Purchase price[c], $	107.66	107.66	107.66	
Carcass value[d], $	66.83	68.93	76.37	5.27
Total feed cost[e], $	15.06	37.57	55.49	
Cost of gain kg[f], $	2.19	2.63	1.70	
Profit[g], $	-55.89	-76.30	-86.78	

[a]WH = wheat hay, SBH = soybean hulls, GR = grain ration.
[b]Standard error of estimate.
[c]Average price of ewes at beginning of trial.
[d]Average value ewes were sold for.
[e]Average cost of ration per ewe.
[f]Cost of ration per weight gain in kg.
[g]Profit = (carcass value) – (purchase rice + tot feed cost).

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DEVELOPMENT AND CONSUMER ACCEPTANCE OF A PRE-COOKED GOAT MEAT PRODUCT

Curry Dawson, Gretchen G. Hilton, Mandy A. Carr, John D. Kellermeier, Jamin H. Phipps, Lacey G. Vinson, and Brian J. May

ABSTRACT

Goat legs (n = 64) were fabricated into 220 roasts that were injected and assigned to one of four treatment groups: control (CON), Italian, Mexican, and prime rib. Roasts (55 roasts/treatment) were cooked in a smokehouse to an internal temperature of 63°C, allowed to chill to 2°C, vacuum packaged, and frozen at -10°C. Roasts were thawed and reheated to 63°C one of three ways (10 roasts/treatment/reheat method); conventional oven, microwave, or boiling. Trained sensory panel analysis was conducted on 120 roasts (30 roasts/treatment) to determine preferred reheating method. The remaining 100 roasts were used for consumer surveys to determine which spice blend was preferred. Roasts were thawed and reheated for 4.5 min in a microwave. Each consumer (n = 200) tasted samples from each treatment to determine juiciness, tenderness, flavor, overall liking, and likelihood to buy. Consumers were also asked to answer demographic questions. When compared to the other two reheating methods, sensory panel scores were lower ($P < 0.05$) for initial juiciness, sustained juiciness, initial tenderness, sustained tenderness, and overall acceptability when goat meat was reheated by boiling. No differences ($P > 0.05$) were found among microwave and oven reheating methods, so microwave reheating was used for the consumer survey. A significant difference was found between spice blends for initial juiciness, sustained juiciness, initial tenderness, sustained tenderness, flavor intensity, characteristic goat flavor, overall acceptability, and warmed-over flavor (WOF). Roasts from the CON group had the lowest flavor intensity score, most characteristic goat flavor, and highest WOF score. Consumers rated prime rib the most tender, juiciest, most flavorful, and the highest for overall liking ($P < 0.05$). Roasts with Italian spices were rated lowest ($P < 0.05$) by consumers for tenderness, juiciness, flavor, and overall liking. Consumers rated roasts with prime rib spices the most likely to buy. Fifty-seven percent of the participants liked roasts with prime rib spice the most followed by Mexican (26%), CON (12%), and Italian (6%). Results of this study indicate a pre-cooked goat meat product can be produced that is acceptable to consumers and possibly marketable in retail stores.

INTRODUCTION

The demand for new red meat products, especially convenient, pre-cooked items, is greatly increasing (Resurreccion, 2003). The red meat industry, especially the beef and pork industries, has taken steps to develop products that are not only low in fat, but also quick, easy, and convenient to prepare and accommodate the changing lifestyles of consumers (Nayga, 1993). However, little research has been done to develop a convenient, pre-cooked goat meat product. The meat goat industry could benefit from gaining red meat consumption market share by providing consumers with a high quality, convenient product.

Meat goats have been used primarily as a control of noxious plants or as part of multi-species grazing systems without much emphasis on meat production (Glimp, 1995). However, recently the demand for goat meat has started to increase. In 2001, 24 million pounds of goat meat were produced and consumed in the United States and another 12.6 million pounds were imported (Shurley, 2002). Currently, live meat goats are sold directly to consumers, or to brokers who in turn sell the animal directly to consumers or retails stores that cater to various ethnic groups (Cosenza et al., 2003). By changing the way meat goats are marketed, profitability of goat meat could increase. One way for the goat meat industry in the U.S. to continue to develop is to provide consumers with a convenient, pre-cooked product that can establish a continuous market share. Therefore, the objective of this study was to develop a palatable, convenient, and economical pre-cooked goat roast.

METHODS AND MATERIALS

Preparing the Roasts

Goat legs (n = 64) were purchased from Texas Tech University (Lubbock, TX) and transported to the Angelo State University Food Safety and Product Development Center (San Angelo, TX) for further processing. Legs were cut into 220 roasts (5.08 cm thick) with a bandsaw and roasts were trimmed of any external fat. All roasts were injected with a 15% injection of a brine mixture of water, 0.05% phosphate, and 1% salt using a Gunther Pickler Injector (model P1632, Koch Supplies, Inc., Kansas City, MO). The roasts were randomly assigned to one of four treatments (55 per treatment): control (CON), Italian, Mexican, and prime rib (Table 1). The roasts were cooked and smoked in a smokehouse (model 1000, Alkar Corporation, Lodi, WI) to an internal temperature of approximately 63°C to achieve a medium-rare degree of doneness (AMSA, 1995). Stage 1 of the smoke cycle lasted for 1.5 h, with the dry bulb set at 65°C and the wet bulb set at 38°C for a relative humidity of 18.5%. Stage 2 of the smoke cycle was set to cook to an internal core temperature of 63°C, with the dry bulb set at 74°C and the wet bulb set at 60°C to equal a 50% relative humidity. After cooking, the roasts were chilled to 2°C, vacuum packed, and frozen at -10°C.

Trained Sensory Panel

Trained sensory panel analysis was conducted on 120 roasts (30 roasts/treatment) to determine the ideal reheating method. The roasts were thawed and reheated to an internal temperature of approximately 63°C one of three ways (10 roasts/treatment/reheat method); conventional oven, microwave (model JES1036PWH, General Electric, Louisville, KY), and boiling. Roasts from each group were reheated in a conventional oven that had been preheated to 176°C. Reheating by boiling was conducted by leaving roasts in the vacuum package and placing them into two liters of boiling distilled water. Reheated roasts were cut into 1 cm × 1 cm × 5.08 cm pieces and placed into serving pans to keep them warm. Samples were served warm to a seven-member panel trained according to Cross et al. (1978). Panelist evaluated the samples based on an 8-point hedonic scale involving initial and sustained juiciness, initial and sustained tenderness, flavor intensity, characteristic goat flavor, and overall acceptability (8 = extremely juicy, tender, intense, characteristic goat flavor, and like extremely; 1 = extremely dry, tough,

Table 1. Ingredient list of three different spice blends for goat roasts

Italian	Mexican	Prime Rib
Italian spice	Coriander	Prime rib rub[a]
Rosemary	Paprika	
Oregano	Garlic powder	
Savory	Ground pepper	
Ground pepper	Cumin	
	Salt	

[a]AC Legg Blend RF-04-161-000 (Calera, AL).

bland, uncharacteristic goat flavor, and dislike extremely). Panelist also evaluated the samples for warmed over flavor (WOF) based on a 5-point hedonic scale (1 = no WOF; 5 = extreme WOF). Samples were served under red lights to mask color differences and panelists were given apple juice and water to cleanse their palates between samples. Results from the trained panel were used to determine the most appropriate reheating method for the consumer panel.

Con*sumer Panel*

The remaining 25 roasts per treatment were used for consumer panels to determine which spice blend was preferred. Each consumer (n = 200) tasted samples from each treatment. Roasts were thawed and then reheated for 4.5 min using a microwave (model JES1036PWH, General Electric, Louisville, KY). Roasts were cut into 1 cm × 1 cm × 5.08 cm pieces and placed into serving pans to keep them warm. Panelist tasted each sample to determine juiciness, tenderness, flavor, and overall liking (6-point scale from "like extremely" to "dislike extremely"). The last attribute of the samples panelist were asked to evaluate was the likelihood to buy the roast (5-point scale from "definitely would buy" to "definitely would not buy") if it was available in a grocery store. After tasting all four samples, consumers were asked which sample was preferred the least and the most. In addition, consumers were asked to answer demographic questions including: marital status, gender, ethnicity, age, household income level, and how many times they have consumed goat in the last month.

Statistical Analysis

Data from the trained sensory panel were analyzed using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC), as a 3 x 4 factorial design (3 cooking methods and 4 spice blends) with individual roast as the experimental unit. Least-square means were computed for each dependent variable, and statistically separated by pair-wise t-test (PDIFF option of SAS) with predetermined $\alpha = 0.05$.

Data from the consumer panel were analyzed using the GLM procedure of SAS as a completely randomized design with spice blend as the treatment and individual roast sample as the experimental unit. Least-square means were computed for each dependent

variable, and statistically separated by pair-wise t-test with predetermined $\alpha = 0.05$. Also, comparisons of frequencies from consumer panelists' responses were tested for significance ($\alpha \leq 0.05$) using Chi-Square tests.

RESULTS AND DISCUSSION

Trained Sensory Panel

When compared to the other two reheating methods, sensory panel scores were lower ($P < 0.05$) for initial juiciness, sustained juiciness, initial tenderness, sustained tenderness, and overall acceptability when goat meat was reheated by boiling (Table 2). These results differ from results reported by Kellermeier (2005), who found no differences ($P > 0.05$) in reheating methods for pre-cooked lamb roasts. No differences ($P > 0.05$) were found between reheating methods for characteristic goat flavor and WOF. Lyon and Ang (1990) reported different results than this study when they found pre-cooked chicken patties varied in their WOF development when heated in either a microwave or a convection oven. Goat may have less WOF development because it is relatively low in fat. A significant difference was found between spice blends for initial juiciness, sustained juiciness, initial tenderness, sustained tenderness, flavor intensity, characteristic goat flavor, overall acceptability, and WOF (Table 3). For both initial and sustained juiciness, prime rib was the juiciest ($P < 0.05$) followed by Mexican. No significant differences were found between the CON or Italian groups for initial or sustained juiciness. No differences ($P > 0.05$) were found among the prime rib or Mexican groups for initial or sustained tenderness. Roasts from the CON group were the toughest ($P > 0.05$), for both initial tenderness (5.85) and sustained tenderness (6.35), when compared to the other treatments. Roasts from the CON group had the lowest flavor intensity score, most characteristic goat flavor, and highest WOF score ($P < 0.05$). Higher WOF scores may be attributed to absence of spices. Many of the spices used in this study have anti-oxidative properties that retard WOF. Common spices with antioxidative properties include rosemary (Brewer and Decker, 1998), cumin, pepper, and garlic products (Rhee and Myers, 2003). Trained sensory panelists detected increasing "cardboard" aromatic intensity in a plain goat meat loaf as compared to a chili seasoned goat meat (Rhee and Myers, 2003). Prime rib was rated the most acceptable overall, followed by Mexican, Italian, and CON ($P < 0.05$).

Consumer Panel

Table 4 shows the demographic characteristics of the 200 consumers that participated in the study. The percentages and numbers are based on consumer responses; however, not all consumers completed all the questions. Fifty-two percent of those surveyed were male while 48% were female. Forty-five percent of participants were married, and 55% were single. Caucasian (72%) and Hispanic (22%) were the most common ethnic groups represented. The majority of the participants reported a household income level of $25,000 or more. Seventy-five percent of the participants had not consumed goat in the previous month, 20% had consumed goat 1 to 3 times in the past month, and 5% had eaten goat 4 or more times in the past month.

Results from the consumer survey show prime rib and Mexican were not different ($P > 0.05$) in tenderness (Table 5). Roasts from the CON and Italian groups were tougher ($P < 0.05$) than prime rib and Mexican roasts, but not statistically

Table 2. Least square means and standard errors for goat roasts of sensory panel ratings for different reheating methods

	Reheating Method		
Trait	Boil	Microwave	Oven
Initial juiciness[c]	5.64[b] (.09)	6.09[a] (.09)	6.10[a] (.09)
Sustained juiciness[c]	6.16[b] (.08)	6.55[a] (.08)	6.64[a] (.08)
Initial tenderness[d]	6.10[b] (.09)	6.48[a] (.09)	6.61[a] (.09)
Sustained tenderness[d]	6.59[b] (.08)	6.92[a] (.08)	7.03[a] (.08)
Flavor intensity[e]	6.08 (.05)	6.21 (.05)	6.07 (.05)
Goat flavor[f]	3.59 (.07)	3.55 (.07)	3.54 (.07)
Overall acceptability[g]	6.00[b] (.09)	6.28[a] (.09)	6.39[a] (.09)
Warmed-over flavor(WOF)[h]	1.05 (.01)	1.03 (.01)	1.01 (.01)

[ab]Means in a row with different superscripts differ ($P < 0.05$).
[c]1 = extremely dry; 8 = extremely juicy.
[d]1 = extremely tough; 8 = extremely tender.
[e]1 = extremely bland; 8 = extremely intense.
[f]1 = extremely uncharacteristic; 8 = extremely characteristic.
[g]1 = dislike extremely; 8 = like extremely.
[h]1 = no WOF; 5 = extreme WOF.

Table 3. Least square means and standard errors for goat roasts of sensory panel ratings for different spice blends

	Treatment			
Trait	CON[k]	Italian[l]	Mexican[m]	Prime Rib[n]
Initial juiciness[e]	5.30[c] (.11)	5.56[c] (.11)	6.24[b] (.11)	6.69[a] (.11)
Sustained juiciness[e]	5.82[c] (.10)	6.01[c] (.10)	6.73[b] (.10)	7.16[a] (.10)
Initial tenderness[f]	5.85[c] (.11)	6.21[b] (.11)	6.67[a] (.11)	6.85[a] (.11)
Sustained tenderness[f]	6.35[c] (.10)	6.71[b] (.11)	7.07[a] (.11)	7.26[a] (.11)
Flavor intensity[g]	5.42[d] (.06)	6.03[c] (.06)	6.30[b] (.06)	6.73[a] (.06)
Goat flavor[h]	5.45[a] (.08)	2.85[b] (.08)	3.05[b] (.08)	2.89[b] (.08)
Overall acceptability[i]	5.51[d] (.10)	5.82[c] (.10)	6.55[b] (.10)	7.00[a] (.10)
Warmed-over flavor(WOF)[j]	1.11[a] (.02)	1.01[b] (.02)	1.00[b] (.02)	1.01[b] (.02)

[abcd]Means in a row with different superscripts differ ($P < 0.05$).
[e]1 = extremely dry; 8 = extremely juicy.
[f]1 = extremely tough; 8 = extremely tender.
[g]1 = extremely bland; 8 = extremely intense.
[h]1 = extremely uncharacteristic; 8 = extremely characteristic.
[i]1 = dislike extremely; 8 = like extremely.
[j]1 = no WOF; 5 = extreme WOF.
[k]CON = Control.
[l]Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[m]Mexican = Coriander, paprika, garlic powder, ground pepper, cumin, salt.
[n]Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

Table 4. Demographic characteristics of consumers attending the Taste of San Angelo and Ram Jam who sampled goat roasts

Trait	No.[a] of consumers	Percent
Gender		
Male	103	52.28
Female	94	47.72
Marital Status		
Married	88	44.90
Single	108	55.10
Ethnicity		
Caucasian	142	72.08
Hispanic	44	22.34
African-American	6	3.05
American-Indian	2	1.02
Other	3	1.52
Age, yr		
18 to 25	71	36.04
26 to 35	32	16.24
36 to 45	36	18.27
46 to 55	33	16.75
56 to 65	19	9.64
Over 65	6	3.05
Household Income Level		
<$10,000	43	22.99
$10,000 to 14,999	4	2.14
$15,000 to 24,999	1	0.53
$25,000 to 34,999	36	19.25
$35,000 to 49,999	31	16.58
$50,000 to 74,999	28	14.97
$75,000 to 99,999	25	13.37
>$99,999	19	10.16
Goat Consumption[b]		
0	146	74.49
1 to 3	40	20.40
4 to 6	8	4.08
Over 7	2	1.02

[a]Not all consumers who participated in the study provided complete data.
[b]Number of times consumers have consumed goat in previous month.

Table 5. Least square means and standard errors for goat roasts of consumer panel ratings for different spice blends

	Treatment			
Trait	CON[f]	Italian[g]	Mexican[h]	Prime Rib[i]
Tenderness[d]	2.30[b] (.08)	2.43[b] (.08)	1.82[a] (.08)	1.68[a] (.08)
Juiciness[d]	2.38[c] (.08)	2.72[d] (.08)	2.08[b] (.08)	1.81[a] (.08)
Flavor[d]	2.82[c] (.08)	3.26[d] (.08)	2.17[b] (.08)	1.83[a] (.08)
Overall liking[d]	2.79[c] (.08)	3.24[d] (.08)	2.16[b] (.08)	1.90[a] (.08)
Likelihood to buy[e]	2.79[c] (.08)	3.23[d] (.08)	2.24[b] (.08)	1.82[a] (.08)

[abc]Means in a row with different superscripts differ ($P < 0.05$).
[d]1 = Like extremely; 6 = Dislike extremely.
[e]1 = Definitely would buy; 5 = Definitely would not buy.
[f]CON = Control.
[g]Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[h]Mexican = Coriander, paprika, garlic powder, ground pepper, cumin, salt.
[i]Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

different when compared to each other. Consumers rated prime rib the most tender, juiciest, most flavorful, and the highest for overall liking ($P < 0.05$). Roasts with Italian spices were rated lowest ($P < 0.05$) for tenderness, juiciness, flavor, and overall liking. Differences ($P < 0.05$) were found for likelihood to buy. Consumers rated roasts with prime rib spices the most likely to buy, followed by Mexican then CON. Italian roasts were rated least likely to buy. Fifty-seven percent of the participants liked prime rib the most followed by Mexican (26%), CON (12%), and Italian (data not shown in tabular form). When asked which they liked the least, 49 % of consumers reported Italian followed by CON (33%), Mexican (11%), and prime rib (7%). These results agree with previous research. Cosenza et al. (2003) reported that 65% of participants in their consumer survey commented that they would buy the cabrito smoked sausage product being tested.

IMPLICATIONS

The results of this study indicate a pre-cooked goat meat can be produced that is acceptable to consumers and possibly marketable on the retail level. Palatability characteristics can be improved, and the strong goat flavor can be decreased, with certain spices. Results of this study, as well as results from previous research indicate tenderness and flavor as important factors dictating consumer's acceptance of meat. The roasts seasoned with prime rib spice were rated the highest for tenderness, flavor, and overall liking. Also, consumers reported that they would be more likely to buy a roast with prime rib seasoning. Marketing goat meat cooked in this fashion with prime rib seasoning could be profitable in this area of Texas. Additional research is needed to determine price per pound and cost of marketing. Overall, this product has the potential to increase consumer's awareness and acceptance of goat meat and improve goat meat's red meat consumption market share.

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DEVELOPMENT AND CONSUMER ACCEPTANCE OF PRE-COOKED LAMB LEG ROASTS

John D. Kellermeier, Gretchen G. Hilton, Mandy A. Carr, Will R. Hartnett, Jamin H. Phipps, Lacey G. Vinson, and Brian J. May

ABSTRACT

Pre-cooked foods are becoming a wide spread convenience item in today's supermarkets. Lamb legs (n = 60) were fabricated into 240 roasts. Roasts were assigned to one of four treatments. After further processing, roasts were smoked to an internal temperature of 63°C, vacuum packaged, and frozen at -10°C. Roasts were thawed and reheated one of three ways before being served to a trained panel. No differences ($P > 0.05$) were found between reheating methods. The control treatment (CON) was rated higher ($P < 0.05$) for lamb flavor, warmed over flavor, and flavor intensity by trained panelists. Consumers (n = 199) were served samples of roasts to determine preferred spice blend. Consumers rated the prime rib spice the highest ($P < 0.05$) for all palatability attributes and the CON the lowest ($P < 0.05$). Therefore, roasts seasoned with the prime rib rub appear to have the most market potential.

INTRODUCTION

With the ever-increasing trend of both females and males working outside of the home, a demand for convenience and a fast, palatable meal has been on the rise (Salvage, 1999). The red meat industry, especially the beef and pork industries, has taken steps to develop products that are not only low in fat, but also quick, easy, and convenient to prepare to accommodate the changing lifestyles of consumers (Nayga, 1993). Between 1970 and 1989 red meat consumption in the United States fell, especially lamb, decreasing by nearly 50% (Nayga, 1993). It is obvious that the lamb industry needs to regain market share and needs to find a way to rebuild consumer confidence in lamb products.

The biggest change in retail markets between 1988 and 1998 is toward convenience items (Nunes, 1998). Today, consumers tend to be more inclined to pay for the convenience of a pre-cooked, ready-to-eat meal (Nunes, 1998). Unfortunately, little effort has been focused on pre-cooking lamb. With most supermarkets now having a variety of ready-to-eat foods and frozen prepared foods ready for heating (Nayga, 1993), a pre-cooked lamb product seems to be economically marketable and sustainable. The field of ready-to-eat products has been expanded greatly over the past few years in order to meet the convenience demands of consumers. Therefore, the lamb industry needs a product that can achieve market share in home meal replacement to increase the consumption of lamb and reverse the negative opinion that some consumers have about the overall eating satisfaction of lamb. Hopefully, a new pre-cooked product can be a small step in the direction of achieving this goal for the lamb industry. Therefore, the objective of this study was to develop a palatable, convenient, economical pre-cooked lamb leg roast.

MATERIALS AND METHODS

Preparing the Roasts

Lamb legs (n = 60) were purchased from Pak Marketing in San Angelo, Texas. The legs were transported to Texas Tech

University for further processing. First, the patella was removed from the legs and any excess subcutaneous fat was trimmed. The legs were cut into four 3.81 cm roasts with a bandsaw for a total of 240 uniform roasts. The most anterior roast from each leg was labeled roast number one, the next was labeled roast number two, the next most anterior was labeled roast number three, and the most posterior was labeled roast number four for all 60 legs. All roasts were then trimmed free of any external fat and the seam fat containing the poplitenal lymph node was removed. All roasts were injected using a Gunther Pickler Injector (model P1632, Koch Supplies, Inc., Kansas City, MO) with a 15% injection of a brine mixture of water, 0.05% phosphate, and 1% salt. The control roasts were injected in order to allocate consistency between all roasts upon reheating. After the roasts were injected, they were allowed to drain. Three spice blends (Table 1) were formulated (60 roasts/spice blend), and 60 roasts were used as a control group. The roasts were assigned to one of four treatments: control (CON), Italian, Mexican, and prime rib. Roasts within each leg were randomly assigned to one of four treatment groups to achieve an equal number of roasts from each leg location within each treatment. The roasts were cooked and smoked in a smokehouse (model 1000, Alkar Corporation, Lodi, WI) to an internal temperature of approximately 63°C to achieve a medium-rare degree of doneness (AMSA, 1995). The smoke cycle consisted of two stages. Stage 1 lasted for 1.5 h, with the dry bulb set at 65°C and the wet bulb set at 38°C for a relative humidity of 18.5%. Stage 2 was set to cook to an internal core temperature of 63°C, with the dry bulb set at 74°C and the wet bulb set at 60°C to equal a 50% relative humidity. After cooking, the roasts were chilled to 2°C, vacuum packed, and frozen at -10°C.

Trained Sensory Panel

Trained sensory panel analysis was conducted on 120 roasts (30 roasts/treatment) to determine the ideal reheating method and to detect differences between spices for differing palatability characteristics. The roasts were thawed and reheated one of three ways (10 roasts/treatment/reheat method); conventional oven, microwave, and boiling to an internal temperature of approximately 63°C. A conventional oven was preheated to 163°C, four roasts were placed in an aluminum pan, and 250 mL of distilled water was placed in the bottom of the pan. Two roasts were placed on paper plates, covered with wax paper, and reheated in a microwave (model JES1036PWH, General Electric, Louisville, KY). Boiling involved placing each individual roast into unsealed cryovac bags and placing them into pots containing two liters of distilled water. Roasts were cut into 1 cm × 1 cm × 3.81 cm pieces and placed into serving pans to keep them warm. Samples were served warm to a seven-member panel trained according to Cross et al. (1978). Panelist evaluated the samples based on an 8-point hedonic scale involving initial and sustained juiciness, initial and sustained tenderness, flavor intensity, characteristic lamb flavor, and overall acceptability (8 = extremely juicy, tender, intense, characteristic lamb flavor, and like extremely; 1 = extremely dry, tough, bland, uncharacteristic lamb flavor, and dislike extremely). Panelist also evaluated the samples for warmed over flavor based on a 5-point hedonic scale (1 = no WOF; 5 = extreme WOF). Samples were served under red lights to mask color differences

Table 1. Ingredient list of three different spice blends for lamb roasts

Italian	Mexican	Prime Rib
Italian spice	Coriander	Prime rib rub[a]
Rosemary	Paprika	
Oregano	Garlic powder	
Savory	Ground pepper	
Ground pepper	Cumin	

[a]AC Legg Blend RF-04-161-000 (Calera, AL).

and panelists were given apple juice and water to cleanse their palates between samples. Results from the trained panel were used to determine the most appropriate reheating method for the consumer panel.

Consumer Panel

The remaining 30 roasts per treatment were used for consumer panels. Consumer panels were conducted to determine which spice blend was preferred. Each consumer (n = 199) tasted samples from each treatment. Roasts were thawed and then reheated for 3.5 min using a microwave (model JES1036PWH, General Electric, Louisville, KY). Roasts were cut into 1.5 cm × 1.5 cm × 3.81 cm pieces and placed into serving pans to keep them warm. Panelist tasted each sample to determine juiciness, tenderness, flavor, and overall liking (6-point scale from "like extremely" to "dislike extremely"). The last attribute of the samples panelist were asked to evaluate was the likelihood to buy the roast (5-point scale from "definitely would buy" to "definitely would not buy") if it was available in a grocery store. After tasting all four samples, consumers were asked which sample was preferred the least and the most. In addition, consumers were asked to answer demographic questions including: marital status, gender, ethnicity, age, household income level, and how many times they have consumed lamb in the last month. Lastly, consumers were asked to rank in order from one to six what influences their meat purchasing decisions the most: price, convenience, taste, past experience, advertisements/promotions, and other.

Statistical Analysis

Data from the trained sensory panel were analyzed using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC), as a 3 x 4 factorial design (3 cooking methods and 4 spice blends) with individual roast as the experimental unit. Least-square means were computed for each dependent variable, and statistically separated by pair-wise t-test (PDIFF option of SAS) with predetermined $\alpha = 0.05$.

Data from the consumer panel were analyzed using the GLM procedure of SAS as a completely randomized design with spice blend as the treatment and individual roast sample as the experimental unit. Least-square means were computed for each dependent variable, and statistically separated by pair-wise t-test with predetermined $\alpha = 0.05$. Also, comparisons of frequencies from consumer panelists' responses were tested for significance ($\alpha \leq 0.05$) using Chi-Square tests.

RESULTS AND DISCUSSION

Trained Sensory Panel

No differences ($P > 0.05$) were found between reheating methods for initial and sustained juiciness and tenderness, flavor intensity, characteristic lamb flavor, overall acceptability, and WOF. This result is similar to Boles and Parrish (1990), who found microwave reheated pre-cooked pork roasts to be palatable. In contrast with the results of the current study, Lyon and Ang (1990) found that pre-cooked chicken patties varied in their off-flavor development when heated in either a microwave or a convection oven. This could be because lamb contains fewer polyunsaturated fatty acids and the chicken patties were refrigerated and the roasts for this study were vacuum packaged and frozen. No differences ($P > 0.05$) were found for initial and sustained juiciness and tenderness, flavor intensity, characteristic lamb flavor, overall acceptability, and WOF with a spice × reheating method interaction. A significant difference existed between spices for initial and sustained juiciness and tenderness, flavor intensity, characteristic lamb flavor, overall acceptability, and WOF (Table 2). For both initial and sustained juiciness, prime rib was the juiciest ($P < 0.05$), followed by Italian, Mexican, and the CON. According to Romans et al. (2001), the addition of phosphates helps to maintain a juicy product. Therefore, no differences should have been detected between spices for juiciness since all roasts were injected with the same brine percentage. However, certain spices used in the blends helped to increase the products overall juiciness. Prime rib was more tender ($P < 0.05$) compared to the Mexican and the CON; and the CON was the toughest ($P < 0.05$) when compared to other treatments for both initial and sustained tenderness. The most intense flavor, characteristic lamb flavor, and WOF were associated with the CON group when compared to other treatments ($P < 0.05$). Smith et al. (1984) reported adding phosphates to pre-cooked roasts decreases the occurrence of an off-flavor development, and Boles and Parrish (1990) discovered when phosphates were added to roasts, they were more palatable. This indicates that the spices and seasonings used were able to mask lamb flavor and helped to prevent WOF. Prime rib was rated the most acceptable overall, followed by Italian, Mexican, and the CON group ($P < 0.05$).

Consumer Panel

The 199 consumers who participated in the study showed a wide range of demographic characteristics (Table 3). The percentages and numbers are based on all data provided; however, not all of the participants provided complete demographics. Sixty-seven percent of those surveyed were male while 33% were female. Sixty-eight percent of the consumers were married, and 32% were single. The most common ethnic groups represented were Caucasian and Hispanic totaling 98%, with Caucasian totaling 91% of the total consumers surveyed. American-Indian and other ethnic groups comprised the other 2%. Because of the overwhelming percentage of Caucasians in the study and the lack of ethnic diversity, the effect of ethnicity on consumer ratings was omitted. The distribution of age groups that participated in the study was fairly even from age 18 to 55; however, some panelist did fall into the 56 to 65 and over 65 categories. Household income level ranged from less than $10,000 to greater than $99,999 with

Table 2. Least square means and standard errors for lamb leg roasts of sensory panel ratings for different spice blends

	Treatment			
Trait	CON[k]	Italian[l]	Mexican[m]	Prime Rib[n]
Initial juiciness[e]	4.68[d] (.10)	5.46[b] (.10)	4.96[c] (.10)	6.52[a] (.10)
Sustained juiciness[e]	4.84[d] (.10)	5.76[b] (.10)	5.13[c] (.10)	7.15[a] (.10)
Initial tenderness[f]	6.00[c] (.12)	6.90[ab] (.12)	6.62[b] (.12)	7.05[a] (.12)
Sustained tenderness[f]	6.27[c] (.11)	7.23[ab] (.11)	6.94[b] (.11)	7.35[a] (.11)
Flavor intensity[g]	5.88[a] (.09)	4.85[b] (.09)	4.91[b] (.09)	4.89[b] (.09)
Lamb flavor[h]	5.94[a] (.19)	4.26[b] (.19)	4.30[b] (.19)	4.35[b] (.19)
Overall acceptability[i]	4.01[d] (.10)	6.19[b] (.10)	5.37[c] (.10)	6.84[a] (.10)
Warmed-over flavor(WOF)[j]	1.39[a] (.03)	1.01[b] (.03)	1.05[b] (.03)	1.00[b] (.03)

[abcd]Means in a row with different superscripts differ ($P < 0.05$).
[e]1 = extremely dry; 8 = extremely juicy.
[f]1 = extremely tough; 8 = extremely tender.
[g]1 = extremely bland; 8 = extremely intense.
[h]1 = extremely uncharacteristic; 8 = extremely characteristic.
[i]1 = dislike extremely; 8 = like extremely.
[j]1 = no WOF; 5 = extreme WOF.
[k]CON = Control.
[l]Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[m]Mexican = Coriander, paprika, garlic powder, ground pepper, cumin.
[n]Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

Table 3. Demographic characteristics of consumers attending the San Angelo Stock Show and Rodeo who sampled lamb leg roasts

Trait	No.[a] of consumers	Percent
Gender		
Male	132	67.01
Female	65	32.99
Marital Status		
Married	132	68.39
Single	61	31.61
Ethnicity		
Caucasian	179	90.86
Hispanic	14	7.11
American-Indian	1	0.51
Other	2	1.52
Age, yr		
18 to 25	45	22.96
26 to 35	34	17.35
36 to 45	48	24.49
46 to 55	46	23.47
56 to 65	19	9.69
Over 65	4	2.04
Household Income Level		
<$10,000	19	10.11
$10,000 to 14,999	4	2.13
$15,000 to 24,999	6	3.19
$25,000 to 34,999	36	19.15
$35,000 to 49,999	29	15.43
$50,000 to 74,999	43	22.87
$75,000 to 99,999	34	18.09
>$99,999	17	9.04
Lamb Consumption[b]		
0	141	72.31
1	30	15.38
2	14	7.18
3	5	2.56
4	3	1.54

[a]Not all consumers who participated in the study provided complete data.
[b]Number of times consumers have consumed lamb in previous month.the majority being between $25,000 and $99,999.

seventy-two percent of consumers surveyed had consumed lamb zero times in the previous month followed by 15% and 7% consuming lamb once and twice respectively in the previous month.

Results from the consumer panel are similar to the results from the trained sensory panel for tenderness, juiciness, flavor, and overall liking of the spice blend treatments. Consumers rated prime

rib the most tender, juiciest, most flavorful, and the highest for overall liking ($P < 0.05$) compared to all other treatment groups (Table 4.) The CON was lower ($P < 0.05$) for tenderness, juiciness, flavor, and overall liking compared with other treatments. A difference ($P < 0.05$) existed for the likelihood to buy a roast with prime rib rated the most likely to buy and CON rated the least likely to buy compared to other treatments.

No differences ($P > 0.05$) in tenderness, juiciness, flavor, overall liking, and likelihood to buy between the treatments were found based on differences in demographic data (not shown in tabular form). The percentages for ratings by consumer panelist for tenderness are presented in Table 5. The majority of responses for the tenderness category fell into the upper three categories of "like extremely," "like very much," and "like slightly" for all four treatments. Prime rib was rated "like extremely" a greater percentage of the time ($P < 0.05$) compared to other treatments. The CON and Mexican spices had a higher percentage ($P < 0.05$) for "like slightly" compared to the prime rib, but no difference ($P > 0.05$) existed between the Italian and the prime rib. No differences ($P > 0.05$) existed between treatments for "like very much," "dislike slightly," "dislike very much," and "dislike extremely." For the bottom three categories, prime rib had the lowest total percentage (5%), followed by Mexican, Italian, and the CON at 9%, 10.1%, and 12.2% respectively.

The percentages for ratings by consumers for juiciness are presented in Table 6. A majority of the responses for prime rib fell into the "like extremely," "like very much," and "like slightly" categories, while responses from the other three treatments were comprised mainly in the "like very much," "like slightly," and "dislike slightly" categories. Consumers chose "like extremely" a higher ($P < 0.05$) percentage of the time and "like slightly" and "dislike slightly" a lower ($P < 0.05$) percentage of the time for prime rib compared to the other three treatments. A higher percentage ($P < 0.05$) existed for the "dislike very much" category for the CON compared to other treatments. No differences ($P > 0.05$) were found between treatments for the "like very much" and "dislike extremely" categories, however the "dislike extremely" category was marked zero times and the "dislike very much" was marked only 0.5% for the prime rib.

Consumer panelist ratings for flavor percentages followed the same trend as juiciness scores (Table 7). The top four categories comprised 88.9%, 94%, 92.5%, and 96% of the CON, Italian, Mexican, and prime rib responses, respectively. Prime rib received a higher ($P < 0.05$) percentage of responses for the "like extremely" category compared to other treatments and the Mexican spice received a significantly higher percentage of responses than the CON for the same category. Prime rib was chosen significantly fewer times for "like slightly" compared to other treatments and a lower ($P < 0.05$) percentage of the time for "dislike slightly" and "dislike very much" compared to the CON. No differences ($P > 0.05$) were found for the "like very much" and "dislike extremely" categories between treatments.

The percentages of consumer ratings for overall liking of different spice blends are presented in Table 8. A majority of the responses fell into the "like very much," "like slightly," and "dislike slightly" categories for the CON, Italian,

Table 4. Least square means and standard errors for lamb leg roasts of consumer panel ratings for different spice blends

	Treatment			
Trait	CON[f]	Italian[g]	Mexican[h]	Prime Rib[i]
Tenderness[d]	2.31[c] (.08)	2.01[b] (.08)	2.09[b] (.08)	1.69[a] (.08)
Juiciness[d]	3.06[c] (.08)	2.67[b] (.08)	2.84[b] (.08)	1.86[a] (.08)
Flavor[d]	3.03[c] (.08)	2.77[b] (.08)	2.59[b] (.08)	1.91[a] (.08)
Overall liking[d]	2.95[c] (.08)	2.71[b] (.08)	2.64[b] (.08)	1.90[a] (.08)
Likelihood to buy[e]	2.95[c] (.08)	2.71[b] (.08)	2.64[b] (.08)	1.93[a] (.08)

[abc]Means in a row with different superscripts differ ($P < 0.05$).
[d]1 = Like extremely; 6 = Dislike extremely.
[e]1 = Definitely would buy; 5 = Definitely would not buy.
[f]CON = Control.
[g]Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[h]Mexican = Coriander, paprika, garlic powder, ground pepper, cumin.
[i]Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

Table 5. Percentages of each rating by consumer panelist for tenderness of samples from different spice blends of lamb leg roasts

	Treatment			
Rating Scale	CON[c]	Italian[d]	Mexican[e]	Prime Rib[f]
Like extremely	28.8[b]	37.4[b]	31.7[b]	53.5[a]
Like very much	33.3	36.8	41.2	31.8
Like slightly	25.8[a]	15.7[ab]	18.6[a]	9.6[b]
Dislike slightly	7.1	6.1	6.5	3.0
Dislike very much	5.1	4.0	2.0	2.0
Dislike extremely	0.0	0.0	0.5	0.0

[ab]Percentages in a row with different superscripts differ ($P < 0.05$).
[c]CON = Control.
[d]Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[e]Mexican = Coriander, paprika, garlic powder, ground pepper, cumin.
[f]Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

Table 6. Percentages of each rating by consumer panelist for juiciness of samples from different spice blends of lamb leg roasts

	Treatment			
Rating Scale	CON[c]	Italian[d]	Mexican[e]	Prime Rib[f]
Like extremely	8.6[b]	12.8[b]	7.1[b]	41.9[a]
Like very much	28.9	33.7	32.0	37.9
Like slightly	27.4[b]	31.1[b]	35.5[b]	15.7[a]
Dislike slightly	22.8[b]	16.3[b]	18.8[b]	4.0[a]
Dislike very much	9.6[a]	3.1[b]	3.6[b]	0.5[b]
Dislike extremely	2.5	3.1	2.0	0.0

[ab]Percentages in a row with different superscripts differ ($P < 0.05$).
[c]CON = Control.
[d]Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[e]Mexican = Coriander, paprika, garlic powder, ground pepper, cumin.
[f]Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

Table 7. Percentages of each rating by consumer panelist for flavor of samples from different spice blends of lamb leg roasts

	Treatment			
Rating Scale	CON[d]	Italian[e]	Mexican[f]	Prime Rib[g]
Like extremely	7.0[c]	12.6[bc]	17.3[b]	44.0[a]
Like very much	25.6	24.6	31.0	33.3
Like slightly	37.7[a]	41.2[a]	29.0[a]	13.6[b]
Dislike slightly	18.6[b]	15.6[ab]	15.2[ab]	5.1[a]
Dislike very much	9.1[b]	3.5[ab]	4.1[ab]	2.5[a]
Dislike extremely	2.0	2.5	1.5	0.5

[abc]Percentages in a row with different superscripts differ ($P < 0.05$).
[d]CON = Control.
[e]Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[f]Mexican = Coriander, paprika, garlic powder, ground pepper, cumin.
[g]Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

Table 8. Percentages of each rating by consumer panelist for overall liking of samples from different spice blends of lamb leg roasts

	Treatment			
Rating Scale	CON[c]	Italian[d]	Mexican[e]	Prime Rib[f]
Like extremely	7.6[b]	10.7[b]	12.6[b]	42.7[a]
Like very much	30.5	29.6	33.2	37.2
Like slightly	30.0[a]	40.3[a]	34.2[a]	13.1[b]
Dislike slightly	21.8[b]	12.8[b]	15.1[b]	4.0[a]
Dislike very much	8.1[b]	4.1[ab]	3.5[ab]	2.5[a]
Dislike extremely	1.0	2.6	1.5	0.5

[ab]Percentages in a row with different superscripts differ ($P < 0.05$).
[c]CON = Control.
[d]Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[e]Mexican = Coriander, paprika, garlic powder, ground pepper, cumin.
[f]Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

and Mexican spices, whereas "like extremely" and "like very much" constituted 79.9% of the responses for the prime rib. No differences ($P > 0.05$) were found between treatments for the "like very much" and "dislike extremely" categories. Prime rib was rated higher ($P < 0.05$) for "like extremely" compared to other treatments. The CON was significantly higher for "dislike very much" compared to prime rib, and the CON, Italian, and Mexican were chosen a higher percentage ($P < 0.05$) for "like slightly" and "dislike slightly" compared to the prime rib spice. These results reinforce Cassard et al. (1965) who noted tenderness and flavor were the two most important factors in determining overall lamb satisfaction.

Therefore, the roast seasoned with the prime rib would be the most likely to sell in a grocery store setting for pre-cooked lamb roast. This was evident by the consumers rating of likelihood to buy a roast seasoned by each treatment. Prime rib results showed that consumers chose "definitely would buy" or "probably would buy" 77.9%, compared to 38.1%, 42.4%, and 45.8% for CON, Italian, and Mexican spices respectively. "Probably would buy," "may or may not buy," and "probably would not buy" were the most common ($P < 0.05$) answers for the CON and Mexican spice. Consumers chose "probably would buy" and "may or may not buy" a higher ($P < 0.05$) number of times compared to the other options for the Italian spice. The prime rib spice received a common answer ($P < 0.05$) of "definitely would buy" and "probably would buy" compared to other choices and "probably would not buy" and "definitely would not buy" were ranked lower ($P < 0.05$) than the other categories.

While demographics had no significant effect on tenderness, juiciness, flavor, overall liking, and likelihood to buy; significant effects were found between demographics and which spice blend was preferred the most and the least. Marital status and gender (Table 9), age (Table 10), and household income level (Table 11) all showed differences ($P < 0.05$) for the spice blend preferred the most and least. Both married and single consumers preferred the prime rib spice

Table 9. Percentages of spice blend preferred most and least based on marital status and gender

	Preferred Most				Preferred Least			
Trait	CON[d]	Italian[e]	Mexican[f]	Prime Rib[g]	CON[d]	Italian[e]	Mexican[f]	Prime Rib[g]
Marital Status								
Married	11.63[b]	10.08[b]	11.63[b]	66.67[a]	41.86[a]	23.26[b]	24.81[b]	10.08[c]
Single	6.56[b]	8.20[b]	4.92[b]	80.33[a]	34.43[a]	34.43[a]	24.59[a]	6.56[b]
Gender								
Male	6.11[b]	9.16[b]	8.40[b]	76.34[a]	45.80[a]	23.66[b]	22.90[b]	7.63[c]
Female	19.05[b]	9.52[b]	11.11[b]	60.32[a]	25.40[ab]	34.92[a]	26.98[ab]	12.70[b]

[abc]Percentages in a row with differing superscripts for preferred most and preferred least differ ($P < 0.05$).
[d]CON = Control.
[e]Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[f]Mexican = Coriander, paprika, garlic powder, ground pepper, cumin.
[g]Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

Table 10. Percentages of spice blend preferred most and least based on age

	Preferred Most				Preferred Least			
Age, yr	CON[c]	Italian[d]	Mexican[e]	Prime Rib[f]	CON[c]	Italian[d]	Mexican[e]	Prime Rib[f]
18 to 25	4.5[b]	11.4[b]	2.3[b]	81.8[a]	38.6[a]	31.8[a]	27.3[a]	0.5[b]
26 to 35	14.7[b]	8.8[b]	5.9[b]	70.6[a]	47.1	17.7	17.7	17.7
36 to 45	14.6[b]	10.4[b]	12.5[b]	62.5[a]	35.4[a]	31.3[a]	25.0[ab]	8.3[b]
46 to 55	10.9[b]	6.5[b]	15.2[b]	67.4[a]	35.6[a]	31.1[ab]	22.2[ab]	11.1[b]
56 to 65	5.6[b]	11.1[b]	11.1[b]	72.2[a]	42.1	15.8	31.6	10.5
Over 65	0.0	0.0	0.0	100.0	33.3	33.3	33.3	0.0

[ab]Percentages in a row with differing superscripts for preferred most and preferred least differ ($P < 0.05$).
[c]CON = Control.
[d]Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[e]Mexican = Coriander, paprika, garlic powder, ground pepper, cumin.
[f]Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

Table 11. Percentages of spice blend preferred most and least based on household income level

	Preferred Most				Preferred Least			
Income	CON[c]	Italian[d]	Mexican[e]	Prime Rib[f]	CON[c]	Italian[d]	Mexican[e]	Prime Rib[f]
<$10,000	5.3[b]	5.3[b]	0.0[b]	89.5[a]	36.8	36.8	26.3	0.0
$10,000 to 14,999	0.0	25.0	0.0	75.0	75.0	0.0	25.0	0.0
$15,000 to 24,999	16.7	16.7	16.7	50.0	50.0	16.7	33.3	0.0
$25,000 to 34,999	14.7[b]	5.9[b]	5.9[b]	73.5[a]	38.2[a]	32.4[ab]	20.6[ab]	8.8[b]
$35,000 to 49,999	10.3[b]	13.8[b]	3.6[b]	72.4[a]	48.3	24.1	13.8	13.8
$50,000 to 74,999	9.5[b]	4.8[b]	11.9[b]	73.8[a]	37.2[a]	32.6[a]	23.3[ab]	7.0[b]
$75,000 to 99,999	5.9[b]	17.7[b]	17.7[b]	58.8[a]	39.4	21.2	27.3	12.1
>$99,999	11.8[b]	5.9[b]	11.8[b]	70.6[a]	35.29	11.8	35.3	17.7

[ab]Percentages in a row with differing superscripts for preferred most and preferred least differ ($P < 0.05$).
[c]CON = Control.
[d]Italian = Italian spice, rosemary, oregano, savory, ground pepper.
[e]Mexican = Coriander, paprika, garlic powder, ground pepper, cumin.
[f]Prime rib = AC Legg Blend RF-04-161-000 (Calera, AL).

the most and the CON the least ($P < 0.05$) compared to other treatments. Males and females reported the same results, preferring the prime rib spice the most ($P < 0.05$) compared with other treatments. Males ranked the CON as being preferred the least ($P < 0.05$), followed by Italian and Mexican, and then by prime rib. Females ranked the Italian spice as being preferred the least in terms of percentages and higher ($P < 0.05$) than roasts seasoned with prime rib. All age groups from 18 to 65 preferred the prime rib spice ($P < 0.05$) over the other treatments. No significant differences for the spice preferred the least was found in age groups of 26 to 35, 56 to 65, and over 65. While the percentage of these three age groups favors a higher percentage preferring the CON the least, the percentages are not different due to a small number of consumers that fell into these groups. The remaining age groups did not have a particular treatment that was preferred the least ($P > 0.05$), but the CON did contain the highest percentage in all three. The 18 to 25 age group chose the prime rib spice fewer ($P < 0.05$) times as the least favorite compared to other treatments. All income levels preferred

the prime rib spice higher ($P < 0.05$) than the other treatments except for the $10,000 to $14,999 and $15,000 to $24,999 groups were no significant differences were found due to the small number of consumers that comprised these two groups. No income level rated one particular spice as the least ($P > 0.05$) favorite over the other treatments, however the $25,000 to $34,999 and the $50,000 to $74,999 preferred the CON least a greater number of times ($P < 0.05$) compared to the prime rib spice. It is also worthy to note that as income level rose the percentage of consumers that preferred the CON the least declined, and the percentage that preferred the prime rib the least increased. This could be explained by the fact that people with higher incomes tend to consume lamb more often (Nayga, 1993), and therefore, prefer the natural flavor of lamb over stronger spices that mask its flavor.

Consumers are persuaded by many things to reflect what can influence their meat purchasing decisions the most. Percentages are shown in Table 12 that identify what influences consumers' purchasing decisions, who participated in this study. Consumers were asked to rank reheating process. Certain spices have the ability to mask lamb flavor and improve palatability characteristics held in high regard to consumers. An advantage exists to marketing a pre-cooked lamb product that is palatable and convenient. Results from the current study are in agreement with previous research showing tenderness and flavor to be the two most important factors for determining overall eating satisfaction in lamb. The prime rib spice was rated the highest for tenderness, flavor, and overall liking. In turn, consumers constantly said they would definitely or probably buy a roast seasoned in order six items that influence their meat purchasing decisions. An overwhelming majority chose taste (58.9%) and price (24.7%) as the number one responses when asked this particular question. Price, taste, and past experience were all rated the second most important item influencing consumers purchasing decisions at 32.9%, 26%, and 26.8% respectively. Convenience was rated the third and fourth most influential category at 39.2% and 36.1%, respectively. Surprisingly, advertisements were found to be the fifth most influential item at an overwhelming 76.4% and the category marked other was chosen 94.9% of the time as the sixth most influential category. Concluding that consumers hold the taste and price of a product in high regards followed by convenience and past experience.

IMPLICATIONS

The results of this study revealed roasts from lamb legs can be processed and retailed as a pre-cooked product to increase the value of these primal cuts. The addition of phosphates to a brine injection can possibly help to reduce an off-flavor development during the in this manner. Therefore, roasts seasoned with the prime rib spice have the potential to be marketed successfully in this area of Texas. Additional research needs to be done to determine the cost for retailing this product on a price per pound basis. Research also should be conducted to determine if retailing a palatable pre-cooked lamb legs helps to increase consumers' perception of lamb. Also, additional spice combinations and the current spice blends combined with a higher percentage of salt could be researched to encompass a larger consumer population. Further research

Table 12. Percentages of categories that influence consumer's meat purchasing decisions the most

	Rank					
Category	1st	2nd	3rd	4th	5th	6th
Price	24.7	32.9	21.5	16.5	4.4	0.0
Convenience	2.1	12.0	39.2	36.1	7.6	0.0
Taste	58.9	26.0	9.5	5.1	0.6	0.0
Past experience	8.3	26.8	28.0	27.4	8.9	0.6
Advertisements	0.0	2.6	1.9	14.7	76.4	4.5
Other	3.2	0.0	0.0	0.0	1.9	94.9

could be conducted to determine if the injecting of phosphates into the roasts helped to reduce the occurrence of a warmed over flavor. Overall, these products should improve the overall eating quality of lamb and appeal to a large number of new consumers.

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CONSUMER ACCEPTANCE OF PRE-MARINATED GOAT RACKS AND GOAT BREAKFAST SAUSAGE

Jamin H. Phipps, Mandy A. Carr, Gretchen G. Hilton, Brian J. May

ABSTRACT

The objective of this study was to develop a marinated goat rack and goat breakfast sausage product that were acceptable to trained and consumer panels. Goat racks were removed from six carcasses and split to make twelve half racks. The shoulders were removed and lean separated and ground for breakfast sausage. Goat racks were marinated with three different spice blends Prime rib (PR), Mexican (MEX), or Lemon Pepper (LP) and three different sausages Goat (G), Meat Lab (ML), and Owens (O) were made and fed to consumers (n = 79) and a trained sensory panel. The trained panel found PR to be the highest ($P < 0.05$) for initial and sustained juiciness and overall likeness. Consumers also rated PR the highest ($P < 0.05$) for overall likeness. The trained panel rated G sausage highest ($P < 0.05$) for initial juiciness, but no difference ($P > 0.05$) was found for overall likeness between sausage treatments. Consumers rated ML and O higher ($P < 0.05$) in every category; however, all scores for G were favorable. The marinated goat racks could be utilized as a value added product for a niche market which could bring additional profit to the goat industry. The goat sausage could possibly be utilized in the American low fat diet.

INTRODUCTION

The consumer demand for goat meat has been increasing over the last two decades and will continue in the future (Gibson, 1999). Along with the consumer demand, the number of goats globally has increased as well (Morand-Fehr et al., 2004). With these trends in the market, a need for processed goat products is on the rise. The production of value-added products targeted toward the United States consumer and ethnic market will provide an increase in profits for the goat industry (Cosenza et al., 2003).

The development of value-added goat products should have the consumer in mind. The red meat industry has developed low fat products, which the goat industry could follow since goat has little fat content (Nayga, 1993). The demand for goat meat coinciding with an inadequate supply has resulted in a increased price. Although beef and pork lead the value-added market, it may be possible for the goat industry to compete if goat products are available to the consumers at a competitive price.

One problem facing the goat industry is balancing supply and demand. Since goats are seasonal breeders, a flooding of the market can occur at certain times of the year as well as a shortage at other times. Value-added products such as marinated, pre-cooked, or partially cooked and frozen items could allow for a more steady supply as well as provide new products to attract non-traditional goat meat consumers. Therefore, the objective of this study was to develop a marinated goat rack and a goat breakfast sausage product that was accepted by a trained and consumer panel.

MATERIALS AND METHODS

Product Preparation

Six goat carcasses were purchased from Producers Lamb and Goat in San Angelo, TX, and transported to the Angelo State University Meat Laboratory. The carcasses were fabricated to remove the racks to be marinated, and the shoulders removed and boned to provide trim for the breakfast sausage. The foresaddle and hindsaddle were split between the 12th and 13th rib. The racks were removed by separating the shoulder from the rack between the 4th and 5th rib to make an 8 rib rack.

The racks were then split down the back bone using a band saw, the chine bone removed, and the ribs cut down to 2.54 cm in length. The half racks were assigned to one of three marination blends (Table 1) with four half racks/marination blend. Recipe A (Prime rib = PR) was a black pepper base rub, Recipe B (Mexican = MEX) was a Mexican base rub and Recipe C (Lemon Pepper = LP) was a lemon pepper base rub. The 12 half racks were injected (Gunther Injector; Model P1632, Koch Equipment, Inc., Kansas City, MO) with a brine solution that consisted of water, salt, and phosphate. Spices were added at a rate of 3% spice blend to total water weight and injected to increase the pre-cooked weight (green weight) by 10%. After each treatment, the injector was cleaned by running clean water throughout for a minimum of 5 min. Once the injection process was complete, all racks were then allowed to drain for 5 min. The racks were then lightly rubbed with their respective spice blend and packaged, then allowed to marinate for 10 d at 40°C and then frozen at -20°C. The breakfast sausage was made from the shoulders (prepared similar to IMPS 204). All lean tissue was removed from the shoulders and first ground through a 1.91 cm plate and then placed trough the grinder again using a 0.64 cm plate. The ground goat trim was then placed in a mixer with the spices used for Angelo State University breakfast sausage (Old Plantation Blend 10; Calera, AL) and mixed approximately 5 min. After mixing, the mixture was placed into a vacuum stuffer (Model VF50; Handtmann Inc., Deutchland, Denmark) and stuffed into plastic chubs and clipped closed. The sausage was then placed in the freezer at -20°C. The same amount of pork breakfast sausage made by Angelo State University (Meat Lab = ML) and also a name brand breakfast sausage (Owens = O) from the retail market was also frozen at -20°C. The frozen chubs of sausage were sliced into 1.75 cm thick patties on a band saw to achieve uniformity and placed in a vacuum package bag, labeled by treatment, sealed, and placed back in the freezer.

Trained and Consumer Sensory Panel

Three separate groups of consumers, (n = 25/group), were asked to assist in the evaluation of the products on two consecutive Fridays with the offer of a package of jalapeno pork sausage as an appreciation gift for their participation. A rack from each treatment was thawed at 2°C prior to the time allotted for cooking. The racks were cooked in a conventional oven to an internal temperature of 71°C (about 75 min) to achieve a medium degree of doneness (AMSA, 1995). They were then sliced into 1.27 cm sections and cut into four pieces and fed to consumers. The consumers were presented with a piece of each treatment and asked to evaluate tenderness, juiciness, and overall flavor on a 6 point scale (1 = like extremely; 6 = dislike extremely). They were also asked which sample they

Table 1. Ingredient list of three different marination blends for goat racks

Recipe A	Recipe B	Recipe C
Prime Rib Rub[a]	Coriander	Lemon Pepper
	Paprika	Black Pepper
	Garlic	Cajun Spice
	Ground Pepper	
	Cumin	
	Salt	

[a]AC Legg (Calera, AL).

preferred and questions about demographic information (gender, ethnicity, age, income, and times last month consumed goat). Along with the consumer testing, a trained sensory panel testing was conducted according to Cross et al. (1978). The preparation of the meat was the same as for the consumer panel. The trained panel evaluated juiciness, tenderness, flavor intensity, goat flavor, and overall acceptability on an 8 point scale (8 = extremely juicy, tender, intense, characteristic, and like; 1 = extremely dry, tough, bland, uncharacteristic, and dislike).

The sausage was allowed to thaw at 4°C prior to cooking. The patties were cooked, using George Forman grills (Salton Model GR38WHT, Lake Forest, IL), to an internal temperature of 71°C to achieve a medium degree of doneness (AMSA, 1995). The consumers were fed the three treatments of sausage and asked to rate the sausages on a 6 point scale of like extremely to dislike extremely for juiciness, cohesiveness, flavor and also which one they preferred. The trained panel tested the products for juiciness, cohesiveness, flavor intensity, goat flavor, and for overall acceptability (8 = extremely juicy, cohesive, intense, characteristic, and like; 1 = extremely dry, non-cohesive, bland, uncharacteristic, and dislike).

Fat Analysis on Sausage Patties

The fat content of each sausage treatment was analyzed using the Univex FA73 fat analyzer (Univex, Salem, NH). Five patties from each treatment were randomly chosen and the percentage fat was recorded for each sample using the procedure provided by Univex.

Statistical Analysis

Data from the trained sensory panel was analyzed using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC) with the rack or sausage sample serving as the experimental unit. Least square means were calculated for each dependent variable, and statistically separated by pair wise t-test (PDIFF option) with predetermined $\alpha \leq 0.05$.

Data from the consumer panel was analyzed using the GLM procedure of SAS as a completely randomized design with spice blend as the treatment and individual rack sample or sausage piece eaten by a consumer serving as the experimental unit. Least square means were calculated for each dependent variable, and statistically separated by pair wise t-test with predetermined $\alpha \leq 0.05$. Also, comparisons of frequencies from consumer panelists' responses were calculated using Chi-Square tests (PROC

Table 2. Least square means for trained sensory panel scores of three different spice blends on pre-marinated goat racks

Trait	Spice Blends		
	Lemon Pepper (LP)	Mexican (MEX)	Prime Rib (PR)
Initial Juiciness[z]	5.58[a]	5.47[a]	6.31[b]
Sustained Juiciness[z]	5.97[a]	6.04[a]	6.83[b]
Initial Tenderness[z]	6.50[b]	5.93[a]	6.91[c]
Sustained Tenderness[z]	6.70[b]	6.18[a]	7.25[c]
Flavor Intensity[z]	5.97[b]	5.43[a]	6.13[b]
Goat Flavor[z]	2.50[a]	3.08[a]	3.00[a]
Overall[z]	5.25[a]	5.56[a]	6.39[b]

[z] 8 = extremely juicy, tender, intense, characteristic, and like; 1 = extremely dry, tough, bland, uncharacteristic, and dislike.
[a, b, c]Within a row, means without a common superscript differ ($P < 0.05$).FREQ) and separated according to Ott (1988) at a predetermined $\alpha \leq 0.05$.

RESULTS AND DISCUSSION

Trained Sensory Panel

The goat racks marinated with prime rib seasoning were rated highest by the trained panel (Table 2) for almost all categories. Racks with PR seasoning were rated higher ($P < 0.05$) for initial and sustained juiciness. Hayes (2006) found that when meat was enhanced with salt, juiciness scores tended to increase. The PR spice blend had the highest concentration of salt in the mix; therefore, the salt may have been the reason behind its higher score. As for initial tenderness, all spice blends were different from each other. Mexican (MEX) spice was lowest (5.93; $P < 0.05$), while lemon pepper (LP) fell in the middle (6.70; $P < 0.05$), and PR was ranked highest (6.91; $P < 0.05$). Sustained tenderness was similar to initial tenderness as each spice blend was different ($P < 0.05$) from each other, where MEX had the lowest value (6.18; $P < 0.05$), followed by LP (6.70; $P < 0.05$), and PR which was rated the highest (7.25; $P < 0.05$). The MEX treatment was rated lowest ($P < 0.05$) in flavor intensity when compared to both LP and PR. Characteristic goat flavor was not different ($P > 0.05$) for the different spice blends with each treatment described as moderately or very uncharacteristic of goat flavor. For overall acceptability, PR was preferred the most ($P < 0.05$) compared to the other treatments of MEX and LP that were not different ($P > 0.05$).

The trained panel evaluated the sausage patties (Table 3) and the goat sausage (G) scored highest ($P < 0.05$) for initial juiciness. Meat lab (ML) was lower ($P < 0.05$) than G, but higher ($P < 0.05$) than Owens (O). The trained panel found G and ML were juicier ($P < 0.05$) after extended chewing (sustained juiciness) than O. Both G and ML sausage were a coarser ground product and may have allowed for more moisture and fat to be held in the product until chewing compared to the finer grinding technique used for the Owens sausage. The G was the most cohesive ($P < 0.05$), followed by ML and O. Gadiyaram and Kannan (2004) also found goat sausage had similar cohesiveness scores as pork sausages. Treatments G and ML were coarse ground and mixed until salt soluble proteins were

Table 3. Least square means for trained sensory panel evaluations of three different types of breakfast sausage

Trait	Types of Sausage		
	Goat (G)	Meat Lab (ML)	Owens (O)
Initial Juiciness[z]	6.41[a]	5.93[b]	4.75[c]
Sustained Juiciness[z]	6.66[a]	6.50[a]	5.50[b]
Cohesiveness[z]	6.56[a]	5.31[b]	3.39[c]
Flavor Intensity[z]	6.39[a]	6.56[a]	5.58[b]
Goat Flavor[z]	3.87[a]	2.08[b]	1.47[c]
Overall[z]	5.77[a]	6.39[a]	6.02[a]

[z] 8 = extremely juicy, cohesive, intense, characteristic, and like; 1 = extremely dry, non-cohesive, bland, uncharacteristic, and dislike.
[a, b, c]Within a row, means without a common superscript differ ($P < .05$).

extracted and binding properties where maximized thus promoting higher cohesiveness score. The O sausage was ground fine commercially which made a smaller fat and lean particle promoting a more "crumbly" texture and thus a lower cohesiveness score. As for flavor intensity, G and ML were rated more intense ($P < 0.05$) than O. Characteristic goat flavor was most noticeable ($P < 0.05$) in the sausage made with goat lean and fat (G); however, it was scored as "moderately uncharacteristic goat flavor" indicating a milder goat flavor than was expected. The ML and O sausage patties were each rated with less ($P < 0.05$) characteristic goat flavor as expected (2.08 and 1.47, respectively) indicating a product with little to no goat flavor noticeable. No significant differences between treatments were indicated for overall acceptability as all patties were either slightly or moderately like.

Consumer Panel

Demographic variation was seen for most categories of the consumer panel (Table 4). More variation in ethnicity would have been desirable and may have influenced some responses as few Hispanic individuals participated and that sector traditionally consumes more goat in the region where the study was conducted. However, the sampled population (non-goat eating public) would be the target audience for both test products.

Consumer responses for marinated goat racks are found in Table 5. As for overall likeness, the consumer panel liked PR better ($P < 0.05$) than the LP. The PR and LP spices were rated higher ($P < 0.05$) for tenderness than MEX. Carr et al. (2004) stated tenderness is the number one trait that consumers look for in meat thus allowing the relationship between tenderness and overall likeness for PR. The PR treatment was also rated higher ($P < 0.05$) for juiciness and flavor than MEX

Table 4. Demographic percentages by categories for consumers (n = 79) sampling goat racks marinated with different spices and three different sausage patties

Characteristic	Percentages
Gender	
Female	41.56
Male	58.44
Ethnic	
Asian	1.27
Caucasian	93.67
Hispanic	5.06
Age	
18 - 25	22.78
26 - 35	16.46
36 - 45	6.33
46 - 55	22.78
56 - 65	26.58
66 +	5.06
Income	
< 10,000	12.82
10,000 - 14,999	3.85
15,000 - 24,999	2.56
24,000 - 34,999	8.97
35,000 - 49,999	8.97
50,000 - 74,999	24.36
75,000 - 99,999	10.26
> 99,999	28.21
Times in Last Month Consumed Goat	
0	74.68
1	16.46
2	5.06
3	2.53
4 +	1.27
Preference of Racks	
Lemon Pepper	24.68
Mexican	22.78
Prime Rib	53.16
Preference of Sausage Patties	
Goat	9.09
Meat Lab	46.75
Owens	44.16

Table 5. Least square means for consumer evaluation of three marinated goat racks

Trait	Spice Blends		
	Lemon Pepper (LP)	Mexican (MEX)	Prime Rib (PR)
Overall Likeness[z]	2.45[a]	2.35[ab]	2.11[b]
Tenderness[z]	1.84[a]	1.55[b]	1.87[a]
Juiciness[z]	2.14[a]	2.05[a]	1.72[b]
Flavor[z]	2.50[a]	2.45[a]	2.02[b]

[z]1 = like extremely, 6 = dislike extremely.
[a, b]Within a row, means without a common superscript differ ($P < 0.05$).

or LP. Behrends et al. (2005) found that juiciness and tenderness values given by consumers have a direct reflection of overall like. It should be noted that every category mean was equivalent to "like very much" or higher for the marinated goat racks.

Consumer panel evaluation of the three different types of sausages (Table 6) found ML and O higher ($P < 0.05$) in overall likeness and flavor as compared to G. Goat was less liked ($P < 0.05$) in the category of cohesiveness compared to the others, but still rated as "like very much" for the category. As for juiciness, ML was juicier ($P < 0.05$) than G, but G still was rated on average "like very much."

Fat Analysis

No difference ($P > 0.05$) in fat content was found between ML (16.2%), O (16%), or G (17.6%) sausage. The fat content of the goat sausage in this study was found to be high (17.6%) when compared the 3.05 – 5.67% reported by Rhee et al. (1997). This could be contributed to the fact that goat meat used in this study came from the shoulders where more seam fat can be found and Rhee et al. (1997) used the whole carcass thus utilizing the lean tissue from the leg and providing for a leaner end product.

IMPLICATIONS

Both value-added products in this study were found to be acceptable to the consumers. Consumers had preferences in each category, but all were acceptable. The marinated goat rack and goat breakfast sausage were products that could be targeted toward non-traditional goat consumers. One problem with a value-added product is that it is more expensive for the consumer. This may pose a problem as goat meat, in general, is an expensive product, thus limiting feasibility. With that in mind, products of this nature may be more suitable for a niche market. The marinated goat rack may have a more promising future in the high-end restaurants where price and portion size are not as important. The goat breakfast sausage may find its place in the low fat food section and may be able to compete with turkey sausage and other low fat sausages.

Table 6. Least square means for consumer evaluation of three different types of sausage

Trait	Types of Sausage		
	Goat (G)	Meat Lab (ML)	Owens (O)
Overall Likeness[z]	3.05[a]	1.96[b]	2.03[b]
Cohesiveness[z]	2.41[a]	1.68[b]	1.97[b]
Juiciness[z]	2.16[a]	1.82[b]	2.00[ab]
Flavor[z]	2.92[a]	1.94[b]	1.94[b]

[z]1 = like extremely, 6 = dislike extremely.
[a, b]Within a row, means without a common superscript differ ($P < 0.05$).

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PERFORMANCE AND MICROBIAL COMPARISON OF SHEEP FROM WOOL AND HAIR BREEDS

Lacey G. Vinson, Mandy A. Carr, Gretchen G. Hilton, Micheal W. Salisbury

ABSTRACT

The objective of this study was to investigate the differences in performance, carcass traits, and microbial shedding of sheep from wool and hair breeds. Lambs from wool, crossbred and hair sheep (n = 45) were weighed every 28 d to a harvest weight corresponding with frame score. At harvest, pelt and carcass contamination, and carcass data were collected. Hair sheep had both the lightest ($P < 0.05$) initial and final weights and were fed the longest ($P < 0.05$). Crossbred lambs had the least ($P < 0.05$) 12th rib fat and lowest ($P < 0.05$) numerical USDA Yield Grade, while having the largest ($P < 0.05$) leg circumference. Crossbreed lambs also had the highest ($P < 0.05$) fecal *E. coli* counts. Breed × harvest and pen × harvest interactions for microbial loads were found. Further research could determine how hair sheep could be implemented into crossbreeding systems.

INTRODUCTION

Rambouillet and Rambouillet × Suffolk are two breeds of sheep found throughout West Texas. These sheep can survive in drought conditions while producing a desirable wool fleece and a lean, muscular carcass. Breed characterization for performance and carcass traits is imperative for identifying genetic resources for producing lean, desirable lamb and for understanding how alternative breeds can be utilized in some production systems (Snowder et al., 1994).

In recent years, the decline in the number of sheep being fed and the loss of funding for the Wool Incentive have weakened the sheep industry (USDA, 1993). The increased difficulty and cost of shearing compared to the decreased value of wool have kept sheep numbers across the United States at an all-time low. However, sheep that do not grow wool are becoming increasingly popular among producers desiring easier care, low-maintenance animals, as these sheep do not need to be shorn (Burke et al., 2003).

Reports indicate pathogenic bacteria have been found in sheep pelts (Meyer et al., 2001). Therefore, researchers have hypothesized that because the hair sheep breeds have no wool, their pelts will trap less microbial contamination. During pelt removal, pelts from wool sheep tend to roll up and touch the carcass, leaving microbial contamination on the carcass. It is speculated that the absence of wool and the thickness of the hide on hair sheep will result in less carcass contamination. Consequently, a need exists to further investigate the differences in performance, carcass traits, microbial shedding and microbial carcass contamination between wool and hair sheep breeds. Therefore, the objective of this project was to investigate the differences in performance, carcass traits, microbial shedding, and contamination among wool and hair sheep breeds.

MATERIALS AND METHODS

Lambs

This project consisted of lambs of both wool breeds and hair breeds: Rambouillet (a wool sheep, n = 16), Rambouillet × Suffolk (a wool sheep, n =

16), and Rambouillet × Dorper × St. Croix × Katahdin (a hair sheep, n = 15). Lambs were obtained from donations or raised at the Angelo State University ranch.

Feeding and Harvest Weight Determination

Once the lambs arrived at the Angelo State University Ranch, they were placed on a common diet according to Talley (2002). The lambs were treated with anthelmintic, vaccinated against enterotoxemia, and given a 14 d adjustment period. On d 1, the lambs were weighed and assigned a frame score corresponding to a target harvest weight (Phillips, 1994). While on feed, lambs were weighted every 28 d. The lambs were fed to a uniform harvest weight that coincided with the frame score assigned. Lambs given a frame score of "small" were harvested at approximately 43 to 49 kg. Lambs assigned a "medium" frame score were harvested at approximately 50 to 58 kg. "Large" frame lambs were harvested between approximately 59 to 61 kg (Snowder et al., 1994; Tatum et al., 1998).

Microbial Contamination

Microbial shedding data were collected at the time of harvest at Ranchers' Lamb of Texas. Before harvest, fecal grab samples were collected from eight animals per breed type. Samples were serially diluted in phosphate buffer, plated on APC and *E. coli*/Coliform Petrifilm (3M, St. Paul, MN). *E. coli*/Coliform Petrifilm were incubated at 35° C for 48 h. Total coliform counts were determined after incubation for 24 h, and *E. coli* counts were read after 48 h of incubation. APC Petrifilm plates were also incubated at 35° C for 48 h before being read.

Microbial and Carcass Data Collection

Immediately post-mortem, a sample was taken with sponge swab kits (Nasco Corporation, Ft. Atkinson, WI) on the pelt midline of each of the eight chosen animals per breed type. Final microbial samples were taken from each animal from which a fecal grab sample was collected when the carcasses reached the end of the harvest floor, but before washing. After spray chilling approximately 24 h post-mortem, all data was collected for USDA Quality (USDA QG) and Yield Grade (USDA YG) including fat thickness at the 12^{th} rib, adjusted fat thickness (ADJFT), leg score (LS), leg confirmation score leg circumference, flank streaking, and maturity (USDA, 1992).

Statistical Analysis

Data were analyzed using GLM procedures of SAS (SAS Institute, Cary, NC). Each individual animal was considered the experimental unit for all individual animal and carcass data (ADG, USDA YG, USDA QG, other carcass traits and microbial contamination), and each pen of four lambs was the experimental unit for feed efficiency data. Least squares means were separated using the PDIFF option of SAS at a predetermined significance of $\alpha = 0.05$.

RESULTS AND DISCUSSION

Weight Gains and Growth Characteristic

Initial weights and final weights were lower ($P < 0.05$; Table 1) for the hair sheep than for the other two breeds in this study. McClure et al. (1991) found similar results, as hair sheep-sired lambs had lower initial weights (23.0 kg) and final weights (44.1 kg) than lambs from Rambouillet and Hampshire (another terminal sire breed) sires. Snowder and Duckett (2003) found lambs sired by

Table 1. Least square means (SEM) for weight gain and feed efficiency of lambs within each breed group

	Breed		
Trait	Hair Sheep[c]	Wool Sheep[d]	Crossbreed[e]
Initial weight, kg	30.09[a] (0.86)	35.69[b] (0.82)	35.22[b] (0.82)
Final weight, kg	42.75[a] (1.01)	49.52[b] (0.97)	50.55[b] (1.25)
Days on feed	79.17[a] (4.43)	57.22[b] (4.26)	53.18[b] (5.49)
Total gain[f], kg	19.03 (1.26)	15.37 (1.21)	16.49 (1.56)
ADG[g], kg	0.24 (0.02)	0.27 (0.02)	0.31 (0.02)
Efficiency[h], kg	3.63 (0.28)	2.95 (0.28)	2.90 (0.28)

[a,b]Means within a row with different superscripts differ ($P < 0.05$).
[c]Hair Sheep breed = Rambouillet × Dorper × St. Croix × Katahdin.
[d]Wool Sheep breed = Rambouillet.
[e]Crossbreed = Rambouillet × Suffolk.
[f]Total amount of weight gained (kg) by sheep in each specific breed group.
[g]ADG = (Final wt-Initial wt)/DOF.
[h]Efficiency = (Total kg of feed consumed by pen)/(Total gain of pen).

Suffolk rams to have lighter initial and final weights than lambs sired by Dorper rams. Traditional wool and crossbreed lambs were similar ($P > 0.05$) in the number of days on feed before harvest, however, hair sheep lambs were fed longer ($P < 0.05$) before being harvested, as these lambs had lower initial and final weights compared to the other breed groups on trial. This contrasts with results found by Snowder and Duckett (2003), where

Suffolk-sired lambs required a longer amount of time on feed before harvest. No differences ($P > 0.05$) were found among breeds for ADG, total weight gained, or feed efficiency, which contrasts results found by McClure et al. (1991) who found that Hampshire sired lambs had higher ADG than Rambouillet or hair sheep-sired lambs. Because of the small sample size of this study, ADG and feed efficiency did not differ among breeds; however, if the sample size had been increased, differences might have been observed between breeds for ADG and feed efficiency. Staab et al. (1999) reported lambs sired by Dorper rams to be on feed fewer days than lambs sired by Rambouillet or Suffolk rams before being harvested. Dorper-sired lambs were also found to be lighter at harvest than both Rambouillet and Suffolk-sired lambs (Staab et al., 1999). Purebred hair sheep lambs had both lighter initial and final weights when compared to purebred wool sheep lambs and lambs from wool × hair sheep according to Bunch et al. (2004). Bunch et al. (2004) also reported ADG of purebred hair sheep to be lower than that of purebred wool sheep or wool × hair sheep.

As expected, lambs given a frame score of "large" were heavier ($P < 0.05$; Table 2) in initial weights than both "medium" and "small" framed lambs, and initial weights for lambs categorized as "small" framed were lower ($P < 0.05$) than

Table 2. Least square means (SEM) for weight gain of lambs within frame score groups

	Frame		
Trait	Large[d]	Medium[e]	Small[f]
Initial weight, kg	38.60[a] (0.65)	33.23[b] (0.66)	29.17[c] (1.29)
Final weight, kg	53.68[a] (0.77)	47.46[b] (0.78)	41.67[c] (1.53)
DOF	62.90 (3.40)	65.00 (3.41)	61.67 (6.70)
Total weight[g], kg	17.81 (0.96)	17.79 (0.97)	15.30 (1.91)
ADG[h], kg	0.30 (0.01)	0.28 (0.01)	0.25 (0.03)

[a,b,c]Means within a row with different superscripts differ ($P < 0.05$).
[d]Large frame = approximate harvest weight of 59 to 61 kg.
[e]Medium frame = approximate harvest weight of 50 to 58 kg.
[f]Small frame = approximate harvest weight of 43 to 49 kg.
[g]Total amount of weight gained (kg) by sheep in each specific breed group.
[h]ADG = (Final wt-Initial wt)/DOF.

both "medium" and "large" framed lambs. Tatum et al. (1998a) also found "large" frame feeder lambs to have heavier initial and final weights than "medium" and "small" frame lambs and "small" frame lambs had the lowest initial and final weights of the three frame score divisions. Assigned frame scores had no effect ($P > 0.05$) on days on feed (DOF), or ADG, while on feed.

A breed × frame interaction was found for total weight gained while on feed.Wool sheep and crossbred sheep in the "small" frame category gained less weight ($P < 0.05$) than the other breed × frame combinations. Wool sheep and crossbreed lambs in the "small" frame category gained less ($P < 0.05$) weight while on feed than all other breed and frame combinations. No breed × frame interactions were found for initial weight, final weight, DOF, or ADG. Bunch et al. (2004) found target harvest weights for lambs from traditional wool breeds and crosses between these breeds to be between 52 and 57 kg, and target harvest weights for hair sheep to be between 45 and 50 kg. Hair sheep in this trial were harvested between 35 and 50 kg. One explanation for contrasts could be differences in initial weights of hair sheep lambs in this study as compared to other studies, as well as, differences in feed rations, climate, and weather patterns. The hair sheep in this trial had lower initial weights than hair sheep in other trials.

Carcass Characteristics

Carcass traits of lambs within the three breed groups are displayed in Table 3. Fat thickness at the 12th rib was less ($P < 0.05$) for crossbred lambs than for traditional wool sheep. Hair sheep were similar ($P > 0.05$) in 12th rib fat thickness to both traditional wool and crossbreed lambs. Notter et al. (2004) determined lambs sired by Dorper rams had greater 12th rib fat thickness than lambs sired by Dorset rams. Snowder et al. (1994) found purebred Rambouillet lambs to have greater 12th rib fat thickness than Targhee, Columbia, or Polypay lambs. Bunch et al. (2004) reported contrasting to this study, as traditional wool lambs had less 12th rib fat than hair sheep lambs.

Contrasting results found in this study can be explained by several factors. Previous research was conducted using

Table 3. Least square means (SEM) for carcass traits of lambs within each breed group

Trait	Breed		
	Hair Sheep[c]	Wool Sheep[d]	Crossbreed[e]
HCW[f], kg	25.55 (0.65)	25.54 (0.63)	26.70 (0.83)
Dressing Percent, %	51.66 (0.87)	49.99 (0.84)	52.10 (1.10)
12th rib Fat Thickness, cm	0.63[ab](0.05)	0.74[a] (0.05)	0.51[b] (0.08)
Adj. fat thickness, cm	0.71[a] (0.05)	0.74[a] (0.05)	0.53[b] (0.05)
Confirmation Score[g]	11.25 (0.19)	11.26 (0.18)	11.52 (0.24)
Leg Score[h]	11.12[b] (0.24)	10.83[b] (0.23)	12.00[a] (0.03)
Leg Circumference,cm	26.21[b] (0.28)	26.65[b] (0.26)	27.68[a] (0.35)
Flank Streaking[i]	11.71 (0.35)	11.11 (0.34)	10.89 (0.45)
USDA QG[j]	11.54 (0.28)	11.16 (0.27)	11.00 (0.36)
USDA YG[k]	2.95[ab](0.24)	3.29[a] (0.23)	2.37[b] (0.31)

[a,b]Means within a row with different superscripts differ ($P < 0.05$).
[c]Hair Sheep breed = Rambouillet × Dorper × St. Croix × Katahdin.
[d]Wool Sheep breed = Rambouillet.
[e]Crossbreed = Rambouillet × Suffolk.
[f]Hot Carcass Weight, kg.
[g]Leg Confirmation Score (15 = High Prime, 14 = Average Prime, 13 = Low Prime, 12 = High Choice, 11 = Average Choice, 10 = Low Choice, 9 = High Good).
[h]15 = High Prime, 14 = Average Prime, 13 = Low Prime, 12 = High Choice, 11 = Average Choice, 10 = Low Choice, 9 = High Good.
[i]15 = High Prime, 14 = Average Prime, 13 = Low Prime, 12 = High Choice, 11 = Average Choice, 10 = Low Choice, 9 = High Good.
[j]USDA Quality Grade (15 = High Prime, 14 = Average Prime, 13 = Low Prime, 12 = High Choice, 11 = Average Choice, 10 = Low Choice, 9 = High Good).
[k]USDA Yield Grade = ((12th rib fat thickness × 10) + 0.4).

purebred hair sheep. In this study, the genetics of three different hair sheep breeds in combination with genes from a traditional wool breed, in this case Rambouillet, possibly increased the level of hybrid vigor for carcass traits and feed efficiency for these lambs. In previous research, lambs were fed diets consisting primarily of either barley or corn. In this study, the basis of all four diets was cracked milo. Climate differences and weather changes could also explain some differences found in this study. Adjusted fat thickness (ADJFT) was lower ($P < 0.05$) for crossbreed lambs than for hair or wool sheep. These results were expected because 12th rib fat thickness is indicative of the amount of fat over the entire carcass.

Crossbreed lambs had higher ($P < 0.05$) leg scores (LS) than the other two breeds. Notter et al. (2004) found lambs sired by hair sheep rams to have greater LS than lambs sired by Dorset rams. Snowder et al. (2004) reported purebred Rambouillet lambs to have lower leg scores than Columbia, Targhee, or Polypay lambs. McClure et al. (1991) found leg scores to be highest (12.70) for lambs sired by Hampshire rams, and lowest (8.30) for purebred hair sheep lambs. Lambs from both traditional wool

sheep and hair sheep exhibited similar ($P > 0.05$) LS. Also, crossbreed lambs exhibited greater ($P < 0.05$) leg circumferences than the other two breeds, while hair sheep and traditional wool lambs displayed similar ($P > 0.05$) leg circumferences. Leg confirmation score and leg circumference measurements indicate the overall muscling of a carcass. These values were used to measure the carcass muscling, as in this study; it was impossible to measure ribeye area using ultrasound or a dot grid. The higher leg scores and circumferences seen in the crossbreed lamb carcasses indicate that these carcasses were more muscular overall than carcasses from traditional wool and hair sheep. Yield Grades (USDA YG) were similar ($P > 0.05$) for wool and hair sheep breeds. Crossbreed lambs had lower ($P < 0.05$; leaner) USDA YG than traditional wool lambs, but similar ($P > 0.05$) to hair sheep lambs. In contrast, Staab et al. (1999) found YG to be similar between lambs sired by Suffolk rams and those sired by Dorper rams. Snowder et al. (2004) reported similar calculated YG results to this study, as Rambouillet lambs were found to have a calculated YG of 3.3. Bunch et al. (2004) reported contrasting results, as hair sheep lambs had higher USDA YG than lambs from wool sheep. No differences ($P > 0.05$) among the breeds were found for hot carcass weight (HCW), dressing percent, leg confirmation score, flank streaking or USDA Quality Grade (USDA QG). The similarities between breeds for dressing percent were expected because the HCW of the lambs were similar among breeds. Staab et al. (1999) determined USDA Quality Grade to be higher for Suffolk-sired lambs 11.15) than for Rambouillet-sired lambs (11.00) and Dorper-sired lambs (10.70).

Microbial Contamination

Crossbreed lambs had higher ($P < 0.05$; Table 4) fecal *E. coli* counts than lambs from traditional wool sheep or hair sheep lambs, which were similar ($P > 0.05$) to each other. A possible explanation for these results relates to the length of time that crossbreed lambs were on feed. Earlier studies indicated the Crossbreed lambs were on feed for the shortest amount of time. While no differences were found to indicate that crossbred lambs exhibited an increase in ADG or feed efficiency, it is possible that these lambs exhibit an increase in microbes in the GI tract, helping to break down feed into nutrients and being shed as bypass protein (Lema et al., 2002).

No differences ($P > 0.05$) were found between breed groups for fecal coliform counts, pelt coliform counts, carcass coliform counts, pelt *E. coli* counts, carcass *E .coli* counts, fecal APC counts, pelt APC counts, or carcass APC counts. Fecal coliform counts and fecal *E .coli* counts were higher ($P < 0.05$; Table5) for harvest group 1 than for harvest group 2. No differences ($P > 0.05$) were found between harvest groups for pelt coliform counts, carcass coliform counts, pelt *E. coli* counts, carcass *E. coli* counts, fecal APC counts, pelt APC counts, and carcass APC counts. The results reported in Table 5 may also reflect changes in weather patterns, as lambs harvested in group 1 were harvested during December. During December, weather patterns had changed to decreased periods of sunlight and day length with increasing amounts of precipitation. Therefore, more precipitation remained in the research pens as stagnant water. Lambs harvested in group 2 were harvested at a time when weather

Table 4. Aerobic Plate Count (APC) and *E. coli*/Coliform Petrifilm counts ($\log_{10}$) with standard errors of the mean for lambs within each breed group

	Breed		
	Hair Sheep[c]	Wool Sheep[d]	Cross Breed[e]
Coliforms, fecal	7.22 (7.49)	7.41 (7.46)	7.80 (7.46)
Coliforms, pelt	1.95 (1.98)	2.24 (1.95)	2.55 (1.95)
Coliforms, carcass	1.48 (0.92)	1.05 (0.92)	1.16 (0.92)
E. coli, fecal	5.43[b] (6.25)	5.85[b] (6.22)	6.81[a] (6.22)
E. coli, pelt	1.87 (1.92)	2.07 (1.89)	2.38 (1.89)
E. coli, carcass	1.31 (0.92)	0.87 (0.89)	1.00 (0.89)
APC, fecal	5.83 (6.72)	6.20 (6.69)	7.20 (6.69)
APC, pelt	5.75 (6.06)	6.48 (6.03)	5.76 (6.03)
APC, carcass	5.29 (4.74)	5.29 (4.74)	4.98 (4.71)

[a,b]Means within a row with different superscripts differ ($P < 0.05$).
[c]Hair Sheep breed = Rambouillet × Dorper × St. Croix × Katahdin.
[d]Wool Sheep breed = Rambouillet.
[e]Crossbreed = Rambouillet × Suffolk.

Table 5. Aerobic Plate Count (APC) and *E. coli*/Coliform Petrifilm counts ($\log_{10}$) with standard errors of the mean for lambs within each harvest group

	Harvest Group	
	1[c]	2[d]
Coliforms, fecal	7.83[a] (7.34)	5.16[b] (7.35)
Coliforms, pelt	2.44 (1.88)	2.16 (1.90)
Coliforms, carcass	1.21 (0.84)	1.30 (0.86)
E. coli, fecal	6.69[a] (6.15)	4.97[b] (6.17)
E. coli, pelt	2.29 (1.80)	1.97 (1.82)
E. coli, carcass	1.03 (0.80)	1.15 (0.82)
APC, fecal	7.07 (6.61)	5.49 (6.63)
APC, pelt	5.41 (5.93)	6.43 (5.95)
APC, carcass	4.88 (4.52)	5.42 (4.54)

[ab]Means within a row with different superscripts differ ($P < 0.05$).
[c]Harvest group 1 = December 16, 2004.
[d]Harvest group 2 = January 18, 2005.

conditions were warmer with increased amounts of sunlight during daytime hours to aid in the evaporation of precipitation.

Breed × harvest group interactions were found for both pelt and carcass APC counts (Table 5). The traditional wool lambs harvested in group 2 displayed higher ($P < 0.05$) pelt APC counts than hair sheep lambs from harvest 1, hair sheep lambs from harvest 2, traditional wool lambs from harvest 1, and crossbred lambs from harvest 2, but similar ($P > 0.05$) pelt APC counts to crossbred lambs from harvest 2. Hair sheep lambs from harvest 1 and 2, traditional wool lambs from harvest 1, and crossbreed lambs from harvest 1 had similar ($P > 0.05$) pelt APC counts to crossbreed lambs from harvest 2. Hair sheep lambs from harvest 1 had lower ($P < 0.05$) carcass APC counts than all of the breed groups in harvest 2, but were similar ($P > 0.05$) to lambs from harvest 1. Hair sheep lambs from harvest 2 had higher ($P < 0.05$) carcass APC counts than hair sheep and crossbreed lambs from harvest 1, but had similar ($P > 0.05$) counts to all traditional wool lambs, and also crossbreed lambs from harvest 2. Traditional wool lambs from harvest group 1 had lower ($P < 0.05$) carcass APC counts than those from harvest 2, but had similar ($P > 0.05$) carcass APC counts to all hair sheep lambs and crossbreed lambs from harvest group 1. Traditional wool lambs from harvest group 2 had similar ($P > 0.05$) carcass APC counts to all other breeds in group 2. Crossbreed lambs from group 1 had lower ($P < 0.05$) carcass APC counts than all breed groups harvested in group 2, but had similar ($P > 0.05$) carcass APC counts to all lambs from harvest group 1. Crossbreed lambs harvest in group 2 had higher ($P < 0.05$) carcass APC counts than all breeds harvested in group 1, but had similar ($P > 0.05$) counts to both traditional wool and hair sheep lambs from harvest group 2. No breed × harvest interactions were found for fecal, pelt, and carcass coliform and *E. coli* counts, as well as fecal APC counts.

Duffy et al. (2001) found APC carcass counts decreased in the Spring months when temperatures are beginning to warm and day length is increasing. Biss and Hathaway (1995) reported that lambs with long, dirty fleeces at harvest had higher pelt and carcass APC counts when compared to lambs with shorter fleeces. Wool particles along with dirt and fecal contaminants were found on the carcasses of lambs with long wool pelts (Biss and Hathaway, 1995; Sheridan, 1998). Bell and Hathaway (1996) also reported an increase in pelt and carcass APC counts for lambs with long wool pelts. Field et al. (1991) found that lambs with shorn fleeces and lambs with long fleeces did not differ in the amount of aerobic bacteria being transferred to the carcass at pelt removal, which is in contrast with findings from this study. Pelt APC findings could reflect the increased amount of dirt and fecal contaminants trapped in the pelts of traditional wool and crossbred lambs. Increased precipitation and decreased sunlight to aid in evaporation of precipitation results in increased mud and stagnant water in the research pens, therefore increasing the amount of mud and fecal contamination being trapped in long fleeces, such as those of the traditional wool and crossbreed lambs.

Pen × harvest interactions were found for fecal APC, *E. coli*, and coliforms, as well as, pelt and carcass APC counts. Microbial counts for pen × harvest interactions are displayed in Table 7. Fecal coliform counts for lambs in pen 25 harvested in group 1 were higher ($P < 0.05$) than for other lambs. All other fecal

coliform counts were similar ($P > 0.05$). Lambs from pen 25 harvested in group 1 also had higher ($P < 0.05$) fecal *E. coli* counts than all other lambs. Lambs in pen 9 harvested in group 1 also had higher ($P < 0.05$) fecal *E. coli* counts than all other lambs harvested with the exception of lambs from pen 25 (1). With the exception of lambs from pen 25 (group 1) and pen 9 (group 1), lambs from pen 6 harvested in group 1 had higher ($P < 0.05$) fecal *E. coli* counts than all other lambs harvested.

Lambs in pen 25 (group 1) had fecal APC counts that were higher ($P < 0.05$) than all other lambs harvested. Lambs in pen 10 (group 1) displayed fecal APC counts that were higher ($P < 0.05$) than all other lambs harvested with the exception of lambs in pen 10(1). All other lambs had similar ($P > 0.05$) fecal APC counts. Pelt APC counts were highest ($P < 0.05$) for lambs in pen 6 from harvest group 2. Lambs in pen 12 in harvest group 2 had lower ($P < 0.05$) pelt APC counts than lambs in pen 6 (group 2), but higher ($P < 0.05$) than all other lambs harvested. Lambs in pen 22 and 25 (group 2) had lower ($P < 0.05$) pelt APC counts than lambs in pen 6 and 12 (group 2), but had similar ($P > 0.05$) pelt APC counts to lambs in pen 23 (group 2). Lambs in pens 19 and 21 (group 1) exhibited lower ($P < 0.05$) pelt APC counts than all other lambs harvested, except for being similar ($P > 0.05$) to lambs in pen 10 (group 1).

Carcass APC counts were highest ($P < 0.05$) for lambs from pen 12 (group 2). Lambs in pen 25 (group 1) and lambs in pen 8 (group 1) had similar ($P > 0.05$) carcass APC counts. Lambs in pens 6, 7, 10, 18, 21, 22 23and 25 (all from group 2) had similar ($P > 0.05$) carcass APC counts to lambs in pens 8, 6, 9, 10, 19, 22, and 25 (all from group 1). No pen × harvest interactions were found for pelt coliform counts, carcass coliform counts, pelt *E. coli* counts, or carcass *E. coli* counts. The results reported in Table 10 could have been influenced by weather conditions, as well as, pen location in relation to sunlight. Because research pens 18 through 25 are located on the east side of the barn, these pens receive sunlight during the morning hours, and are shaded during the afternoon hours when temperatures are at the warmest during the day. Pens 1 through 17 are on the west side of the barn, and receive sunlight in the afternoon when temperatures are highest. Because pens 18 through 25 receive little afternoon sunlight, these pens will hold stagnant water.

IMPLICATIONS

This study indicates lambs from hair sheep must be fed longer and harvested at lighter weights in relation to frame score than both traditional wool and crossbred lambs to produce carcasses with quality and cutability traits that are acceptable to the packer and consumer, contrasting previous research. This study found crossbred lamb carcasses to have advantages in increased muscling and decreased fat when compared to lambs from hair sheep and traditional wool sheep. However, in this study, as frame size increased, both muscling and fat deposition also increased. Crossbreed lambs had higher fecal *E. coli* counts than both traditional wool and hair sheep, while changing weather patterns and increased precipitation between harvest times likely influenced both APC pelt and carcass microbial loads. Further research is needed to determine the effects of climate and weather patterns on microbial shedding, pelt loads, and carcass loads of sheep. Also, further investigations should

be performed to determine how hair sheep genetics could be implemented into crossbreeding systems where meat production is the primary focus of the producer.

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THE USE OF SELECTIVE MICRO®CLEAN CHLORINE DIOXIDE ON MICROORGANISMS INHERENT TO CHICKEN AND BEEF SURFACES, AS WELL AS INOCULATED MEAT AND SKIN SURFACES

Mandy A. Carr, Lauren L. Hahn, Lacey G. Vinson, and Jamin H. Phipps

ABSTRACT

The purpose of this study was to evaluate effectiveness of Selective Micro®Clean chlorine dioxide solution on bacterial colonies inherent to chicken and beef surfaces, as well as bacteria inoculated onto the surfaces. Skins from chicken thighs (n = 64; 8 per treatment) and beef round steak portions (n = 64; 8 per treatment) were utilized for the first part of the study. Half of the samples were tested for aerobic bacteria, while the other half were inoculated with 1 ml per sample of stock *Enterococcus faecalis* and allowed to attach for 2 min to simulate normal processing conditions. Treatments were spray application of 5, 10, and 20 ppm Selective Micro®Clean solution to exterior surfaces. Serial dilutions were prepared and duplicate samples were enumerated on appropriate Petrifilm™ and incubated at 35˚C for 48 h. Colonies were counted and recorded as colony forming units/ml (CFU/ml). Dilutions exhibiting counts of 25-250 CFU/ml were utilized for data analysis. For the second portion of the study, lean chicken breast tissue portions (n = 32; 8 per treatment) were utilized. Samples were inoculated with a stock *Salmonella* cocktail of *S. typhimurium* and *S. typhi*. Samples were treated, diluted, plated, incubated and counted in the previous manner. No differences ($P > 0.05$) were found between treatments for aerobes found on chicken thigh skins. Treatment with Selective Micro®Clean reduced ($P < 0.001$) colonies of *E. faecalis* on inoculated thigh skins. It was found that 5 ppm was more effective than 20 ppm ($P = 0.0142$) in destroying *E. faecalis* on chicken thigh skins (6.3 log CFU/ml for 5 ppm treatment versus 7.0 log CFU/ml for 20 ppm treatment). Conversely, in beef round steak samples, no advantage of treatment over the control was indicated. *Salmonella* were reduced ($P < 0.05$) by up to 2.9 log CFU/ml with 10 ppm spray application of Selective Micro®Clean. Selective Micro®Clean may find success if implemented into a commercial meat processing setting to reduce occurrence of bacterial contamination on carcasses as well as finished products, especially for poultry.

INTRODUCTION

Reducing microbial populations on meat products is always important to producers, in making safe and wholesome products and meeting quality control specifications, as well as producing a product that stays fresh in market conditions. By applying treatments to meats, microbial populations can be reduced, if not eliminated. Aerobic bacteria, or any bacteria requiring oxygen to live, are inherent to many surfaces, including meat. Aerobes in general, especially *Pseudomonas* species, cause spoilage, reduce shelf life, cause off-odors, and cause meat to turn off-colors. *Enterococcus faecalis* is a microbe that is inherent to the gastrointestinal tract of living animals and is often used in research as it acts similar to *Escherichia coli*, an indicator of sanitation. It is almost

inevitable that meat products will some how become contaminated with GI tract microbes given harvest conditions of both chicken and beef. *Salmonella* species are inherent to the gastrointestinal tract of poultry, but can also be carried by beef and other meat animals. When consumed by people, *Salmonella* spp. and several *E. coli* spp. can cause serious food illness by bacterial intoxication.

Currently, many methods exist to decontaminate meat, including acid sprays, hot water baths, steam vacuuming, and trimming the carcass for visible contaminants. It is important to continue to search for new bactericides for meat products because bacteria can adapt to some treatments, such as acids. In work by Berry and Cutter (2000) it was demonstrated that certain strains of *Escherichia coli* have become resistant to 2% acetic acid used to decontaminate beef carcasses.

Prior to the conception of Selective Micro®Clean, the widespread use of chlorine dioxide was limited to large-scale applications such as public water systems. Chlorine dioxide was reportedly difficult to use, hard to keep in solution, and not easily transported. Generation equipment for chlorine dioxide is costly. However, Selective Micro®Clean chlorine dioxide solution can be made onsite in small quantities, stays in solution better than traditional chlorine dioxide, and is simple to dilute. In several prior studies, chlorine dioxide was used with success in rinse and chill water. However, little work could be found discussing the efficacy of chlorine dioxide applied as a topical spray to meat products. Therefore, the objective of this study was to examine the proficiency of Selective Micro®Clean as a spray in reducing bacterial populations inherent to or inoculated onto beef and chicken surfaces.

MATERIALS AND METHODS

Chicken thigh skins (n = 64, 8 per treatment) were dissected from the exterior of the thigh, and placed on portions of aluminum foil in groups of 8. Four treatment groups were tested for aerobic bacteria, while the other four were inoculated with stock *Enterococcus faecalis*. For aerobic testing, one group was tested without application of Selective Micro®Clean (control). The other three treatment groups were sprayed with Selective Micro®Clean at 5, 10, or 20 ppm. The spray was allowed to set on the skin for 2 minutes to simulate commercial processing time lapse. Samples were then placed individually in stomacher bags, phosphate buffer solution was added to make a 1:9 dilution of skin to water, and the bags were placed in the stomacher for 30 sec at 230 rpm. Then, serial dilutions were prepared. The, 1 ml aliquots of each dilution were plated onto 3M Petrifilm for Aerobic Plate Counts. Duplicate plates were made of each dilution. Plates were then incubated at 35°C for 48 h. Colonies, exhibited as pinkish, red dots, were counted and recorded. Duplicate plates were averaged to produce and average number of colonies per dilution. Dilutions with colony counts between 25 and 250 were used for statistical analysis.

For *Enterococcus* testing, each chicken skin was inoculated with 1 ml stock (1×10^9 CFU/ml). The inoculum was spread evenly over the surface of the skin with a sterile glass rod and allowed to attach for 2 min. Then, as a control, one treatment group was not sprayed (control). The other 3 treatment groups were sprayed with 5, 10, or 20 ppm Selective Micro®Clean and allowed to set for 2

minutes. Serial dilutions were prepared in the same manner previously described. Duplicate plates were made on appropriate 3M Petrifilm. Samples were incubated at 35°C for 48 h. Reddish colonies with a gas bubble around them were counted and recorded. Duplicate plate counts were averaged, and dilutions with colony counts of 15-250 were used for statistical analysis.

Beef lean round steak (n = 32) portions were used for the beef lean aerobic testing. Procedures for beef lean were identical to procedures followed for aerobic testing of chicken skin.

Lean chicken breast tissue samples (n = 32, 8 per treatment) were utilized for *Salmonella* testing. Boneless skinless chicken breasts were split into 2 pieces. One ml of stock *Salmonella* cocktail (2.8 X 10^8 = 8.3 $\log_{10}$ *S. typhimurium* and *S. typhi*) was inoculated onto each sample, spread evenly over the surface with a sterile glass rod and allowed to attach for 2 min. One set of samples was not sprayed (control). The other 3 groups were sprayed with 5, 10, or 20 ppm Selective Micro®Clean and allowed to set for 2 min. Samples were stomached as previously described. Serial dilutions were prepared as previously described and duplicate plates per dilution were made on Bismuth sulfide agar plates. Plates were incubated at 35°C for 24 h. Colonies appearing as dark green to black spots were counted. Duplicate plates were averaged, and statistical analysis performed. Least Square Means were obtained with the General Linear Model procedure of SAS and separated by the PDIFF option at a predetermined $\alpha = 0.05$.

RESULTS AND DISCUSSION

Beef lean testing proved inconclusive (Table 1). Control samples tested had higher CFU/ml than any of the treatments. This could have been due to any number of differences in pre-purchase handling by meat markets. It has been found by other researchers that chlorine dioxide reduced numbers of aerobes on beef, however, higher concentrations of chlorine dioxide were used. Stivarius and others (2002) found 200 ppm chlorine dioxide solution effectively reduced aerobes by 0.72 log cfu/g. Additionally, Emswiler and others (1976) reduced APC by 1.64 log CFU/cm^2 with a 200 ppm chlorine solution sprayed onto beef carcasses. Also, Unda and others (1989) dipped ribeye steaks in a 100 ppm chlorine dioxide solution to reduce APC by 1 log CFU/cm^2.

Chicken skin aerobic plate counts (APC; Table 2) showed no difference between treatments. However, the 5 ppm treatment did have numerically lower CFU/ml. These findings are similar to those of Thiessen and others (1984) who found only a slight reduction of 0.55 log cycle even when using a much higher concentration of ClO_2 at 1,390 ppm. However, ClO_2 was applied by mixing it into rinse water rather than direct spray application. Lillard (1980) reported decreases in APC of 0.87 log cycles on macerated skin samples using concentrations of 400-900 ppm ClO_2 in chill water.

Enterococcus faecalis inoculated onto chicken breasts (Table 3) were most effectively controlled by 5 and 10 ppm applications which reduced CFU/ml by 2.6 and 2.2 log CFU/ml, respectively. The 20 ppm treatment, while different from controls, only had a slightly higher reduction than controls (1.5 reduction in control versus 1.9 reduction for 20 ppm ClO_2). These results are better than those reported by Thiessen and others (1984)

Table 1. Beef lean Aerobic Plate Count when Selective Micro®Clean was applied at various concentrations.

	Control	5 ppm	10 ppm	20 ppm
Aerobes CFU/ml ($\log_{10}$)	4.9[a]	5.1[b]	5.2[b]	5.2[b]

[a,b]Numbers with different superscripts are different ($P < 0.05$).

Table 2. Chicken skin Aerobic Plate Count when Selective Micro®Clean was applied at various concentrations.

	Control	5 ppm	10 ppm	20 ppm
Aerobes CFU/ml ($\log_{10}$)	3.9[a]	3.8[a]	4.2[a]	4.2[a]

[a]Numbers with same superscripts are not significantly different ($P > 0.05$)

Table 3. Chicken skin *Enterococcus faecalis* counts when Selective Micro®Clean was applied at various concentrations.

	Control	5 ppm	10 ppm	20 ppm
E. fecalisi[1] CFU/ml ($\log_{10}$)	7.4[c]	6.3[a]	6.7[a,b]	7.0[b]
Log reduction CFU/ml ($\log_{10}$)	a	2.6[b]	2.2[c]	1.9[a]

[1]*Enterococcus afecalis* inoculated onto surface of chicken skin.
[a,b,c]Numbers with different superscripts are different ($P < 0.05$).

that found a 0.80 log cycle reduction in *E. coli* on macerated chicken breast skin even with a much higher concentration of 1390 ppm ClO_2 (in chill water). Additionally, Lillard (1980) reduced fecal coliforms by 1.26 log cycles on macerated skin samples using concentrations of 400-900 ppm ClO_2 in chill water. It is possible that higher reductions were found in the Selective Micro®Clean study due to the use of breast meat for the study rather than skin. Barnes and Impey (1968) reported that the majority of bacteria on chicken are found within feather follicles and in cuts. Therefore, the bacteria may be protected from treatment on the skin, while being more susceptible to bactericide on the smooth surface of the muscle.

Any of the treatments were effective ($P < 0.05$) on *Salmonella* cocktail inoculated breast meat (2.6, 2.9, and 2.6 log cycles, respectively). In a study by Thiessen and others (1984), treatment of 1,390 ppm ClO_2 in chill water eliminated *Salmonella* incidence on broiler carcasses from a mean occurrence of 97.3% positive carcasses in the plant. Lillard (1980) reported occurrences of *Salmonella* from 8 in 56 carcasses with no ClO_2 to 1 in 96 carcasses testing positive with concentrations of 400-600 ppm ClO_2 in chill water.

CONCLUSION

In this study, Selective Micro®Clean chlorine dioxide solution was effective in reducing bacterial colonies on meat surfaces, especially on lean chicken muscle and toward a mixture of *S. typhimurium* and *S. typhi.* Previous literature suggests that chlorine dioxide is less inhibited by organic matter than other sanitizers such as chlorine. Peeters and others (1989) indicated 0.4 mg of chlorine

Table 4. Skinless chicken breast inoculated with a *Salmonella* cocktail[x] and reductions of colonies by various concentrations of Selective Micro®Clean.

	Control	5 ppm	10 ppm	20 ppm
Salmonella[1] CFU/ml (log_{10})	5.502[a]	6.055[b]	5.779[a,b]	5.931[b]
Log reduction[2] CFU/ml (log_{10})	2.499[b]	2.605[b,c]	2.881[c]	2.071[a]

[1]*Salmonella* inoculated onto surface of chicken breast muscle
[2]Reduction of colonies found on chicken breast tissue based on stock culture enumeration.
[a,b,c]Numbers with different superscripts are different ($P < 0.05$).
[x]Combination of *S. typhimurium* and *S. typhi*.

dioxide per liter of demineralized water significantly reduced infectivity of *Cryptosporidium parvum* oocysts from cattle feces within 15 min of contact. It has been shown to be a very effective sanitizer for food-contact surfaces to destroy organisms including *E. coli*, *Staphyloccus aureus*, as well as several fungi and viruses. Pohlman and others (2002) found a 200 ppm chlorine dioxide followed by 10% trisodium phosphate significantly reduced *E. coli*, coliforms, and aerobic plate counts on inoculated beef trimmings. This treatment also provided a redder overall color to the treated trimmings and no off-odor when compared other antimicrobial treatments including ozonated water and cetylpyridium chloride treatment. Jimenez-Villarreal (2003) and others also indicated improved or maintained instrumental and visual color, taste, cooking characteristics and lack of odor production when chlorine dioxide was used on beef trimmings before grinding. Although not indicated in this study, the authors believe different results may have been seen with an inoculated beef lean product and if a product could have been obtained from a processing facility instead of from a retail outlet from which the handling practices of the meat sample were unknown prior to purchase. Andrews and others (2002) reported lower aerobic and psychrotrophic counts (from 1 to 4 log cycle reductions; reductions increasing with increasing initial concentrations) on shrimp and crawfish sprayed with chlorine dioxide in a high- or low-pressure prewash.

As it is easy to handle, prepare, and test for concentration, Selective Micro®Clean, a chlorine dioxide product, should be very effective as part of a single or multiple intervention strategy program, which might include a chill tank system, production conveyor dunk tank, or in a product or food-contact surface spray. It has been shown to effectively reduce bacterial contamination on meat and skin surfaces in this project and on other products in previous studies highlighted in this report.

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ACCEPTANCE OF SOY PROTEIN SUPPLEMENTATION BY COLLEGE STUDENTS IN THE HEALTH PROFESSIONAL STUDIES: A PILOT PROJECT

Tabitha Lloyd and Mandy A. Carr

INTRODUCTION

The acceptance of soy protein supplementation was conducted to determine if college consumers in a health professional field can find benefit from a protein supplemented product over a one week period. Although soy is listed among the common worldwide food allergens, soy is one of the less prevalent allergen among foods. Allergic responses to the soy are usually characterized by upset stomach, hives, or rashes. Also gastrointestinal intolerance has been noted through research with the use of soy products however, SUPRO, the soy protein isolate utilized in this study is essentially free of carbohydrates that induce flatulence.

Because of the numerous health benefits, soy foods are becoming more common in the American diet. Soy is a great source of protein compared to that found in animal products because they are low in saturated fat and have no cholesterol. Soy foods helps lower LDL (bad) cholesterol and triglyceride levels, decreases risk of developing heart disease, and help prevent osteoporosis. A decrease in the incidence of caner (particularly breast cancer) and increase in bone density is associated with the consumption of soy protein. It also increases your energy naturally, aids in losing weight, balances hormone levels, and supports the immune system.

METHODS AND MATERIALS

The food items used were selected based on responses to a preliminary survey related to food preferences. The products included: Sunny Delight, milk, or Gatorade from the liquid list and chocolate pudding, vanilla yogurt, or apple sauce from the snack list. The items were purchased locally and provided to twenty-five students enrolled in a health professional graduate program at Angelo State University. Two grams of a protein supplement was weighed, packaged, and supplied with two items per day for each of the students. The protein supplement used was a soy protein isolates (SUPRO 760 for the snack items and SUPRO FXP-219D for the liquid items) from Dimension Food Solutions, Inc containing approximately 90% protein.

A pre-trial and post trial survey was conducted. The pre-trial survey questions included: Has the consumer utilized a protein supplement in the past five years? If yes, which type of product, and if taken for six months, what benefit would be expected to gain from a protein supplement? The post trial survey was used to determine if the consumer's energy levels changed while taking the supplement, if they experienced any adverse effects to the product, if a change in muscle tone or mass occurred, and which product they preferred to consume the soy product in.

RESULTS & DISCUSSION

Eighty-three percent of the students participating had not utilized a protein supplement in the past five years. The 17 percent which had consumed a protein supplement, did in the form of a commercially available protein bar or with

protein supplement in powder form mixed with a beverage. An increase in energy, muscle tone, and muscle mass were benefits the students wanted to gain if taking the product for six months. After consuming the commercial product in this project for a week, very little change was noted regarding in their energy level or muscle mass. Some of the students discontinued the product due to adverse effects. An increase in urination, upset stomach, diarrhea, and constipation were some effects experienced, but none considered severe within the week. The majority of the college students (61%) preferred the soy protein supplement blended with the pudding. Next, they chose the orange juice and apple sauce for the product to mix with the supplement.

IMPLICATIONS

As this was a pilot study conducted by an undergraduate student to be used as the basis for a future proposal and possible graduate project, the time frame available for the project was limited. Therefore, after completing the research, it was determined that very little change took place during the week of consumption. The product would need to be consumed over a longer period of time to see any benefits (increase in energy, muscle mass, muscle tone, or weight loss). The number one product consumed was the pudding because it had the least textural change from the original product after the soy protein supplement was added. The orange juice was preferred over the Gatorade because the soy protein was less noticeable once it was mixed together. It was concluded that the soy protein supplement was more acceptable when added into a more viscous (thick) product.

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SENSORY EVALUATION OF LOIN CHOPS FROM DIFFERENT BREEDS OF SHEEP AND GOAT

William R. Hartnett, Mandy A. Carr, Gretchen G. Hilton, Michael W. Salisbury

ABSTRACT

Loin chops from different breeds of sheep and goat were fed to determine if consumers (n = 154) could identify quality differences. The treatment groups included 100%, 50%, and 25% Rambouillet, Dorper, Barbado, and goat. Loin served as the experimental unit in a model that included the independent variable of breed. Consumers preferred ($P < 0.05$) 100% Rambouillet over 50% and 25% Rambouillet, Barbado, and Dorper. Consumers rated 100% Rambouillet the most tender ($P < 0.05$). Goat was rated juicier ($P < 0.05$) than Barbado and 25% Rambouillet, but was not different ($P > 0.05$) from Dorper, 100% & 50% Rambouillet. Flavor was rated similar ($P > 0.05$) for 100% Rambouillet, Dorper, 50% Rambouillet, and goat. These results indicate consumers favor the eating quality of loin chops from traditional wool breeds over hair sheep and hair sheep crosses when evaluating overall likeness, tenderness, and juiciness.

INTRODUCTION

Nayga (1993) reported consumption of lamb in the United States decreased by nearly fifty percent between 1972 and 1989; but lamb is still consumed in the U.S. and abroad. Means et al. (2001) explained the loss of wool incentives to U.S. producers and low wool prices forced emphasis to shift from wool to meat production. Lack of a wool coat, high level of parasite resistance, and elevated vigor are reasons to believe hair sheep could reduce production cost associated with common wool breeds (Notter, 2000) while still producing quality meat.

The Dorper (developed in South Africa), St. Croix, and Barbados Blackbelly (imported from the Caribbean) are considered hair sheep due to a hairy coat that sheds, thus reducing the need for shearing (Wildeus, 1997). In order to reduce production costs associated with wool harvest, sheep producers in the United States could benefit from the use of select hair sheep breeds (Notter, 2000). Wildeus (1997) reported hair sheep and crosses between hair and wool breeds have the ability to reproduce efficiently in low input production systems under poor conditions.

For many years, meat goat production has been an important segment of the livestock industry in developing countries (Morand-Fehr and Boyazoglu, 1999). Glimp (1995) predicted a considerable increase in meat goat production for the U.S. because vast feed resources are available, the populations of ethnic consumers are expanding, and Boer goats are growing in popularity. Between 1980 and 2003, goat populations in developed countries increased by over twenty-eight percent (FAO, 2004). To continue this current growth trend, it is important to develop and market a high-quality product that appeals to customers who do not regularly consume goat meat (Zijderveld, 1987). However, little data exists comparing the meat quality of hair sheep breeds and Boer goats to conventional wool breeds currently used in meat production systems.

MATERIALS AND METHODS

Consumer Testing

A full loin (Lamb IMPS #232, Goat IMPS #11-5-50 1000 4002000 1000302) from each of twenty animals in each of five breed groups (50% Rambouillet, 25% Rambouillet, Dorper, Barbado, and goat) was transported frozen from the Texas Tech University Meat Laboratory to the Angelo State University Management, Instruction, and Research Center. The remaining percentages for the 50% and 25% Rambouillet sheep were comprised of Dorper and St. Croix, both hair sheep. In addition, the goat breed group was comprised of Boer goat crosses. The loins for the 100% Rambouillet breed group were obtained from Ranchers' Lamb in San Angelo, Texas. While frozen, chops from each loin were cut 2.54 cm thick, placed in vacuum packaged bags, and labeled (by breed group and individual animal). Procedures used to conduct the consumer panels for this study were approved by the Angelo State University Institutional Review Board. Consumer sampling was conducted at the Fredericksburg Food & Wine Fest in Fredericksburg, TX, using sixteen panels consisting of up to ten consumers each on one day in October 2004. The chops from every breed group were thawed at 4˚C overnight prior to the consumer sampling. Chops from one animal per breed group were cooked on George Foreman grills (Salton Model GR38WHT, Lake Forest, IL, USA) until the internal temperature of 71˚C was reached (AMSA, 1995). Exterior fat was trimmed and the muscle cut into 1×1×2.54 cm cubes. The samples from each animal were placed in separated sample cups and kept warm using insulated serving dishes. All breeds were assigned a sample letter that was rotated prior to every panel to avoid possible sampling bias. Consumers received loin samples one at a time to evaluate for overall likeness, tenderness, juiciness, and flavor. Evaluation was based on a six point, verbally anchored hedonic scale where 1 = Like Extremely and 6 = Dislike Extremely. After completing the sensory evaluation of the loin chops, consumers completed demographic information including lamb and goat consumption, gender, age, and household income. These cooking procedures were repeated sixteen times throughout the day using a total of one hundred and fifty-four consumers.

Sensory Analysis

Data were analyzed using the general linear model of SAS (SAS Inst., Cary, NC). Loin served as the experimental unit in a model that included the independent variable of breed type. Least-square means were computed and separated by pair-wise t-test (PDIFF option of SAS) at a predetermined $\alpha \leq 0.05$. Consumer demographics were analyzed using frequency function of SAS.

RESULTS AND DISCUSSION

Consumer Demographics

Consumers participating in this study were asked to submit demographic information based on lamb and goat consumption, gender, age, and household income level (Table 1). When asked how many times in the past month they had consumed lamb, over 70% ($P < 0.05$) of the participants responded with zero. In addition, consumers responded with 1 time more often ($P < 0.05$) than 2, 3, or 4. The number of consumers responding with 2, 3, or 4 was similar ($P > 0.05$). Goat consumption followed a similar pattern with over 94% ($P < 0.05$) answering they had not consumed goat in the past month. The remaining participants responded at similar ($P > 0.05$) percentages that they

Table 1. Demographic characteristics of consumers (n = 154) attending Fredericksburg Food and Wine Festival

Characteristic	%
Times lamb was consumed in the last month	
0	70.59[a]
1	16.99[b]
2	9.80[c]
3	1.31[c]
4	1.31[c]
Times goat was consumed in the last month	
0	94.08[a]
1	5.26[b]
3	0.66[b]
Gender	
Female	55.0[a]
Male	45.0[a]
Age, yr	
18 to 25	8.50[c]
26 to 35	20.92[b]
36 to 45	14.38[b]
46 to 55	32.03[a]
56 to 65	16.34[b]
>65	7.84[c]
Household income level, $	
<10,000	0.72[c]
10,000 to 14,999	1.44[c]
15,000 to 24,999	3.60[c]
25,000 to 34,999	6.47[c]
35,000 to 49,999	9.35[c]
50,000 to 74,999	24.46[b]
75,000 to 99,999	10.79[c]
>99,999	43.17[a]

[a,b,c] Means within the same category with different superscripts differ ($P < 0.05$).

month. No difference ($P > 0.05$) was found between genders of the consumer population.

had consumed goat 1 and 3 times in the previous month.

Participants between the ages 18 to 25 and those over 66 made up the smallest ($P < 0.05$) portions of the consumer population (8.5% and 7.84%, respectively). Consumers falling into the 46 to 55 age bracket made up a larger ($P < 0.05$) percentage of the sample group than any other bracket. The 26 to 35, 36 to 45, and 56 to 65 age brackets were all similar ($P > 0.05$) in their percentage of the consumer group surveyed.

Consumers with household incomes less than $10,000, between $10,000 to $14,999, $15,000 to $24,999, $25,000 to $34,999, $35,000 to $49,999, and $75,000 to $99,999 were similar ($P > 0.05$) and made up the smallest portions of the surveyed consumers. Participants with

a household income between $50,000 and $74,999 made up the second ($P < 0.05$) largest group, while consumers earning a household income greater than $99,999 comprised the largest ($P < 0.05$) percentage of this demographic.

Consumer Sensory Evaluation

Consumers used a six point hedonic scale where 1 = Like Extremely and 6 = Dislike Extremely, to evaluate loin chops from each breed type for overall likeness, tenderness, juiciness, and flavor (Table 2). Chops from the 100% Rambouillet and goat were similar ($P > 0.05$) for overall likeness, receiving more favorable scores, at 2.34 and 2.58, respectively. In addition, chops from goat carcasses were not different ($P > 0.05$) from Dorper or 50% Rambouillet chops, but were more desirable ($P < 0.05$) than chops from both 25% Rambouillet and Barbado. In contrast, Bunch et al. (2004) found hair sheep loin chops received greater overall acceptability scores than chops from common wool breeds.

When evaluating tenderness, consumers preferred ($P < 0.05$) chops from 100% Rambouillet carcasses over all other breeds. Chops from Goat were not different ($P > 0.05$) from Dorper or 50% Rambouillet chops; however, they were favored ($P < 0.05$) over both chops from Barbado and 25% Rambouillet carcasses. These results support the findings of Means et al. (2001) who reported Dorper wethers produced chops with higher Warner-Bratzler shear force values than those from Suffolk and Western White-Face sires, indicating Dorper meat was less tender. However, using a trained sensory panel, Tshabalala et al. (2003) reported Boer goat patties to be tougher and chewier than those from Dorper. Chops from 50% Rambouillet, Dorper, Barbado, and 25% Rambouillet were all similar for tenderness scores. However, using an eight point rating system with eight being extremely tender, Snowder and Ducket (2003) found sensory panelists preferred Dorper rib chops over chops from Suffolk sheep, a wool producing meat breed.

Consumers rated 100% Rambouillet chops the juiciest; however, no difference ($P > 0.05$) was observed between chops from 100% Rambouillet and Goat. Chops from goat carcasses were found to be juicier ($P < 0.05$) than chops from both Barbado and 25% Rambouillet, but was not different ($P > 0.05$) from chops produced by Dorper or 50% Rambouillet carcasses. This differs from Tshabalala et al. (2003) who found Dorper patties were juicier than those made from Boer goat carcasses. While chops from 25% Rambouillet were ranked lowest for juiciness, they were comparable ($P > 0.05$) to chops from Barbados and 50% Rambouillet carcasses.

Sensory evaluation of flavor resulted in the fewest differences as loin chops from 100% Rambouillet, Dorper, 50% Rambouillet, and Goat were similar ($P > 0.05$). In an earlier study, Duckett et al. (1999) reported sensory panelists preferred the flavor of Dorper meat over that from Suffolk. Loin chops from 25% Rambouillet sheep were scored least desirable in flavor, but were still similar ($P > 0.05$) in value to those from Barbado. Barbado loin chops were also found comparable ($P > 0.05$) to those from Goat, 50% Rambouillet, and Dorper. Interestingly, Snowder and Duckett (2003) reported flavor was rated similar by sensory panelists; however, rib chops from Dorper lambs were considered more tender and juicy than rib chops from Suffolk lambs.

Table 2. Least square means and standard errors of consumer sensory evaluation of loin chops from different breeds of sheep and goats

Breed	100% R[v]	50% R[w]	25% R[x]	Barbado	Goat [y]	Dorper
Overall[z]	2.34[c]	2.70[ab]	3.00[a]	2.90[a]	2.58[bc]	2.76[ab]
Tenderness[z]	1.86[c]	2.73[ab]	3.06[a]	2.99[a]	2.35[b]	2.73[ab]
Juiciness[z]	2.23[d]	2.75[abc]	3.08[a]	2.92[ab]	2.55[cd]	2.64[bc]
Flavor[z]	2.50[c]	2.75[bc]	3.15[a]	2.89[ab]	2.76[bc]	2.74[bc]

[a,b,c,d] Means within the same row with different superscripts differ ($P < 0.05$).
[v] 100% Rambouillet.
[w] 50% Rambouillet.
[x] 25% Rambouillet.
[y] Boer goat cross.
[z] 1 = Like Extremely and 6 = Dislike Extremely.

IMPLICATIONS

Consumers favored loin chops from 100% Rambouillet over loin chops from hair sheep and hair sheep crosses for overall likeness, tenderness, and juiciness. This indicates hair sheep producers must strive to make improvements for these sensory attributes in order to gain greater acceptance with consumers when compared to traditional Rambouillet lambs. Previous research has shown hair sheep meat to be preferred over meat from Suffolk sheep. While Suffolk sheep produce wool, they are considered a meat breed and are primarily used for meat production by crossing with other meat or wool producing breeds of sheep. Therefore, further research must be conducted to evaluate the sensory differences between hair sheep and crosses produced from wool and meat producing breeds. Loin chops from Boer goat crosses were comparable to those from 100% Rambouillet carcasses for overall likeness, juiciness, and flavor. With continued growth in Boer goat production and an effective marketing strategy, consumption of goat meat could improve and be competitive with lamb in the red meat industry. While vast differences for sensory traits in this study were discovered, it should be noted that all breed groups averaged Like Slightly or better for all sensory characteristics.

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CONSUMER ACCEPTANCE OF FOUR FLAVORED BACON SAMPLES

Tabitha Lloyd, Jamin Phipps, Blake Coates, Andrea Payan, Alfredo Munoz, Dustin Yates, Ross Copeland, Chad George, and Mandy Carr

ABSTRACT

Since bacon is a convenient food, the consumption of it has increased offering a broad market for the industry to expand. The objective in this study was to evaluate consumer acceptance of brine injected pork bellies with additional specialty rubs applied to the bellies. Each belly was injected with the brine solution and then additional treatments were applied to the tissue surface of the pork bellies until they were entirely coated. Sample A was the control and sample B consisted of black pepper. Brown sugar and black pepper was added to sample C, while sample D contained honey and black pepper. After the application was applied, the bellies were then allowed time to smoke. They were then sliced (n = 136), separated, sealed in a vacuum packaging bag, labeled per treatment, and frozen. The consumers were asked to prepare, sample, and evaluate one of each sample. Consumers evaluated appearance, flavor, overall liking, and likelihood to buy (1 = like extremely; 6 = dislike extremely). No difference ($P > 0.05$) was found between the four samples. Eighty-five percent of the consumers did prefer some type of additional application to the pork bellies; however, they were likely to buy all products sampled.

INTRODUCTION

Marinating and injecting is often used to preserve and enhance the flavor of meat items. The brine ingredients of the marinade which help with preservation and flavor enhancement includes: salt (preservative), sodium nitrite (color development, color stability, influences the cured meat flavor, and preservative), sugar (reduces the harshness of salt), and erythorbate (promotes the conversion of nitrites to nitrous oxide). Once the brine solution is injecting into the meat product, the utilization of smoking can improve the shelf-life by reducing both the microbial spoilage and the development of rancidity (Anderson, 2004).

The consumption of bacon has increased because bacon is the ultimate convenience food, always on hand, ready in minutes, and has been part of the popular low-carbohydrate diet trend. Because the utilization of bacon has increased, it is important to have a variety of specialty bacon products available for consumer to add variety to their meals. After pork bellies are injected with a brine solution, a seasoned rub, like honey or black pepper, could be applied to give added flavor. Honey has been applied to meat products as a marinade, dry rub, or a glaze. It provides unique functionality when used as an ingredient including sweetness; because of its high fructose content, it is sweeter than table sugar. Honey also contributes to flavor enhancement as stated in Hashim et al. (1999). The objective in this study was to evaluate consumer acceptance of brine injected pork bellies with additional specialty rubs.

MATERIALS AND METHODS

Sample Preparation

Water, salt, powdered dextrose, praque powder, and sodium erythorbate were added to a warm water solution. Table 1 shows the formulation utilized to pump 8-10 skin-on pork bellies. Once the ingredients were added, the solution was left to chill. The skin was then removed from the four bellies that were chosen to be pumped. Before the actual pumping of the bellies, they were weighed in order to obtain a green weight. The bellies were then injected (Gunther Injector; Model P1632, Koch Equipment Inc., Kansas City, MO) with 2.54 cm spacing and pumped with the cure solution to an increased weight of 10%. Then, the four bellies were cut into equal thirds and the treatments were applied to each section. The sections were identified by treatment. Sample A was the control which no treatment was applied. Sample B consisted of black pepper only, while Sample C contained brown sugar and black pepper (4.4 kg of brown sugar per 0.2 kg of black pepper). Finally, honey and black pepper was applied to sample D. The treatments were applied to the tissue surface until it was entirely coated. After the applications were applied to the bellies, they were laid on smokehouse racks and cooked. The smokehouse (Alkar-RapidPak Inc., Model 700HP, Lodi, WI) cycle was set for two stages. Stage one was a two h smoke on wet bulb at 37.8°C and dry bulb at 60°C cycle; and stage two was a four h smoke on wet bulb at 48.9°C and dry bulb at 87.8°C cycle. The actual cooking process of the smoker took 2.5 h at an ending temperature of 65.6°C. The bellies were sliced (Model 909A, Berkel Southwest, Inc., Grandpairie, TX) into .6 cm thick (n = 136) and two pieces of each treatment were vacuum packaged (Koch Ultravac 2100, Kansas City, MO), labeled per treatment, and frozen at -28.88°C.

Consumer Sampling

The slices of bacon were distributed to consumers which were asked to prepare each sample by pan frying or microwaving which had to be specified on the survey. The consumers were asked to evaluate the samples based on appearance, flavor, overall liking, and likelihood to buy (1 = like extremely; 6 = dislike extremely). They were also asked which sample they liked the most and which one they liked the least. Demographic questions (marital status, gender, ethnicity, age, income) were asked.

Statistical Analysis

The consumer data were analyzed using the GLM procedure of SAS (SAS Institute Inc. 1995, Cary, NC) and each consumer response represented an experimental unit. Least square means were calculated and separated with PDIFF option at an $\propto = 0.05$. Percentages for demographic information were calculated by PROC FREQ function of SAS.

RESULTS AND DISCUSSION

The four different varieties of bacon were similar ($P > 0.05$) regarding the appearance, flavor, overall liking, and likelihood to buy. Overall, consumers liked the four different samples and were willing to buy each one. It could be concluded that not enough difference existed between the treatments to have a strong effect on the consumers' preference. Also people like bacon and will eat it because 80% of the people surveyed consume bacon one or two times during a two week period. In this study conducted by our class, 52 consumers were surveyed and over 75% of them were Caucasian (Table 4). Also, more people

Table 1: Formulation for the injected solution ingredients for 8-10 skin-on pork bellies

Ingredients	Amount (lb)	Amount (oz)	Amount (g)
Water	46	736	20865.25
Salt	4	64	1814.37
Powdered Dextrose	1.5	24	680.39
Praque Powder	0.88	14.08	399.16
Sodium Erythorbate	0.25	4.00	113.40

Table 2: Least square means showing consumer (n = 52) difference between Sample A, Sample B, Sample C, and Sample D for pork bellies

	Sample			
	A[a]	B[b]	C[c]	D[d]
Appearance[e]	2.62[f]	2.56[f]	2.72[f]	2.76[f]
Flavor[e]	2.65[f]	2.38[f]	2.34[f]	2.39[f]
Overall Liking[e]	2.67[f]	2.51[f]	2.53[f]	2.42[f]
Likelihood to Buy[e]	3.00[f]	2.84[f]	2.90[f]	2.75[f]

[a]Sample A = control.
[b]Sample B = black pepper.
[c]Sample C = brown sugar and black pepper.
[d]Sample D = honey and black pepper.
[e]1 = like extremely; 6 = dislike extremely.
[f]Least square means within a row with different superscripts differ ($P < 0.05$).

Table 3: Percent consumers will pay for the different samples of pork bellies and consumer opinion in percent of which pork belly sample was liked the most and least

	Sample			
	A[a]	B[b]	C[c]	D[d]
Price/lb, $				
1.99	65.31	48.94	58.70	63.64
2.49	28.57	23.40	10.87	15.91
2.99	2.04	23.40	19.57	13.64
3.49	4.08	4.26	10.87	6.82
Like most	14.58	27.08	33.33	25.00
Like least	39.58	18.75	22.92	18.75

[a]Sample A = control.
[b]Sample B = black pepper.
[c]Sample C = brown sugar and black pepper.
[d]Sample D = honey and black pepper.

Table 4: Demographic characteristics of consumers in San Angelo

Characteristic	%
Gender	
Female	48.00
Male	52.00
Marital status	
Married	66.00
Single	34.00
Ethnic category	
Caucasian	84.00
Hispanic	14.00
African-American	2.00
Age, yr	
18 to 25	21.28
26 to 35	27.66
36 to 45	4.26
46 to 55	25.53
56 to 65	12.77
66+	8.51
Income level, $	
< 10,000	12.82
10,000 to 14,999	10.26
15,000 to 24,999	0.00
25,000 to 34,999	23.08
35,000 to 49,999	5.13
50,000 to 74,999	12.82
75,000 to 99,999	33.33
> 99,999	2.56

prepared the bacon by pan frying (82%) over microwaving and grilling. Before the study was completed, it was hypothesized that females would rank sample C and D, the brown sugar and honey, over sample A and B, the control and black pepper. Sixty-five percent of the female ranked samples C and D most liked. Both male (40%) and female (39%) ranked sample A as the least liked. The majority (35 out of 52) of the respondents were between the ages 18 to 35 and 46 to 55. The 26 to 35 year olds identified sample D as being most liked and sample B being least liked. Sample C was liked the least (41%) by the 46 to 55 year old people questioned. The number one factor that influences consumer decisions when purchasing meat is taste (31%); therefore, by having a variety of seasoned bacon it gives the consumer an assortment of tasteful products.

IMPLICATIONS

Gaining greater control over quantity and quality has become very important in the highly competitive U.S. food sector. Households want high quality, safe and convenient foods with desirable nutritional qualities. To meet this demand, pork companies are

introducing new products. Also, a more ethnically diverse U.S. population is creating niche marketing opportunities for new pork products. With the new opportunities in the market, developing new specialty and precooked bacon products could increase the sale and consumption of pork bellies. Not only do the U.S. consumers want high quality pork products, but the exporting countries do too. Because the preference of consumers is always changing, it is challenging to serve and satisfy the consumer; therefore, a need for a variety of products is crucial for the success of the industry. For example, as stated in Vonada et al., the International Pork Quality Audit identified variation in lean quality of U.S. pork as an area of needed improvement to serve the needs of customers in Asia. It was surveyed that moderate amounts of seam fat in retail pork belly slices were preferred ($P < 0.05$) by respondents; hence, bellies that displayed visual lean:fat ratios (20 to 40% fat) best suited the preferences of South Korean customers. Bellies with low amounts of seam fat were preferred ($P < 0.05$) over bellies with high amounts of seam fat. When comparing the preference of South Korean customers to U.S. customers, there could be similarity in the preferred amount of seam fat on bacon because consumers evaluate the quality of bacon based on the presence of meat exceeding that of fat. Since the recent new low-carb diet craze, the sale of precooked, prepackaged retail bacon has increased within the last year by 2% (6.6 million pounds). With precooked bacon only representing a fraction of the retail bacon business, it is predicted that it will account for as much as half over the next 10 years. Therefore, to successfully compete, processors will have to provide all the flavors they do in raw bacon, as well as more adventurous ones, such as teriyaki (Spiselman 2006). With the increase in demand the need for specialty products also increases. The study that was complete regarding the four different varieties of bacon shows that 85% of the consumer preferred an application to be added to the product. Also stated in Spiselman (2006), processors have begun to supply foodservice clients with flavors, such as peppered maple and jalapeno to low sodium and low fat, hickory and applewood smoked, bacon products. These specialty products are available in 2 oz. packages of 14 to 16 slices and retailing for $2.99 to $3.99. It has also been determined that it would be more convenient for consumers to provide individual portions. Since consumers are pressed with time, bacon is a great convenient meat source to have on standby.

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CONSUMER ACCEPTANCE OF MARINATED CHICKEN BREASTS FAJITAS

Tabitha Lloyd, Jamin Phipps, Blake Coates, Andrea Payan, Alfredo Munoz, Dustin Yates, Ross Copeland, Chad George, and Mandy Carr

ABSTRACT

The objectives in this study were to duplicate a chicken fajita product and evaluate consumer acceptance of that product and one variation from it. Two treatments (Treatment 1 = Durkee Six Pepper Blend, n = 16 breast halves; Treatment 2 = red pepper, n = 16 breast halves) to boneless, skinless, chicken breast halves, were marinated by immersing, sealed in a vacuum packaging bag, and then tumbled. The halves were dispersed into individual bags (n = 64) and given to the consumer which were asked to prepare however they like, sample, and evaluate one of each sample. Consumers evaluated tenderness, juiciness, flavor, appearance, and overall liking (1 = like extremely; 6 = dislike extremely). They were also asked the likelihood to buy (1 = definitely would buy; 5 = definitely would not buy). The tenderness and juiciness of the product appeared to have no difference to the consumer ($P > 0.05$). The flavor of Treatment 2 was preferred ($P < 0.05$) over Treatment 1 (1.55 vs. 2.11), and the consumers rated the overall liking of Treatment 2 higher (1.50 vs. 2.14; $P < 0.05$); however, the consumer were likely to buy both products.

INTRODUCTION

Pre-seasoned meat products have gained popularity because consumers' preference for easy convenient food has increased. Marinating and injecting products is not only helpful for pre-seasoning, but it can also help improve tenderness, juiciness, and flavor. Historically, marinades were used to pickle items, but now marinades are any liquid that increases the flavor and softens meats. Most marinades contain similar seasonings which include: salt, phosphates, acids, tenderizers, and sugar, (Hashim et al., 1999) that have various functions when applied to a specific type of meat. The functions of these ingredients can increase water holding capacity and moisture retention and decrease cooking loss and warmed over flavor when applied to chicken. In the study from Hashim et al. (1999), chicken (bone-in breast with skin) was marinated by immersing, injecting, and rubbing-on products just before cooking. The results showed immersing the chicken in the marinade presented the best outcome. However, many pork processors inject fresh pork with products containing water, sodium chloride, and flavoring to enhance and maintain the tenderness, juiciness, and flavor of lean pork cuts as stated by Vote et al. (2000). In this study, marinating by immersing and tumbling was used to saturate the boneless skinless chicken breast to give it the desired flavor of fajitas and obtain consumer acceptance.

MATERIALS AND METHODS

Sample Preparation

Phosphate, salt, black pepper, onion powder, garlic powder, Durkee Six Pepper Blend, red pepper, and water was used to season the boneless skinless chicken breast halves (purchased at Sam's Wholesale Club in San Angelo, TX) to give it the flavor that resembles the pre-seasoned Wheeler brand chicken for fajitas. A duplicate of the product was

made and one variation from it. Two treatments were used on the product (Treatment 1 = Durkee Six Pepper Blend, n = 16 breast halves; Treatment 2 = red pepper, n = 16 breast halves). Table 1 shows the formulation utilized to marinate four boneless, skinless, chicken breast halves. Eight breast halves were place in a vacuum packaging bag and then the contents were added. Since 8 chicken breast halves were prepared for marinating at one time all the ingredients from Table 1 were doubled. To ensure safety from contamination and leakage or tearing, the chicken breasts were double bagged and sealed (Koch Ultravac 2100, Kansas City, MO) without pulling a vacuum. The product was then placed in a tumbler (Koch LT15, Kansas City, MO) for 15 min with a 4.54 kg vacuum pulled on the chamber. After the allotted time in the tumbler, the breasts were removed. The breasts were sliced in half and placed into individual vacuum package bags (n = 64) and labeled per treatment. The marinade was split equally between the bags, and the bags were sealed with a vacuum and frozen at -28.88°C.

Consumer Sampling

The breasts were distributed to consumers which were asked to prepare one of each sample in the method of their choice. The consumers were asked to evaluate the samples based on tenderness, juiciness, flavor, appearance, and overall liking (1 = like extremely; 6 = dislike extremely). Consumers were also asked the likelihood to buy (1 = definitely would buy; 5 = definitely would not buy).

Statistical Analysis

The consumer data was analyzed using the GLM procedure of SAS (SAS Institute Inc. 1995, Cary, NC) and each consumer response represented an experimental unit. Least square means were calculated and separated with PDIFF option at an $\propto = 0.05$.

RESULTS AND DISCUSSION

Boneless, skinless, chicken breast halves were similar ($P > 0.05$) regarding the tenderness and juiciness of the breasts; therefore, marinating by immersing and tumbling in the different spices had no effect on these two categories (Table 2). The lack of difference in tenderness and juiciness was anticipated because neither treatment aided in the increase of these characteristics. Behrends et al. (2005) completed a similar test concerning top sirloin steaks and the effect of calcium chloride injection on tenderness. The tenderness of the top sirloin steaks were influenced by the cooking methods not the calcium chloride injection; thus, tenderness and juiciness were not affected in this study by treatment as both cooking methods were identical. A multi-city, retail consumer survey was used to determine whether marinating in calcium chloride postmortem improves consumer and trained sensory panel evaluations of beef loin steaks in Carr et al. (2004). Consumers scored marinated steaks for tenderness, juiciness, flavor, and overall quality higher than control steaks, and the results of the trained panel agreed with the improvement in beef flavor and overall quality. The consumers and trained panel noticed an improvement on the quality of marinated meat and would pay more for that product.

A difference ($P < 0.05$) between Treatment 1 and Treatment 2 existed for flavor, appearance, overall liking, and likelihood to buy. Treatment 1 was formulated to mimic the currently marketed chicken product (Wheeler Chicken for Fajitas), and Treatment 2 was

Table 1: Formulation for the marinade ingredients for four boneless skinless chicken breast halves

Ingredients	Amount (g)
Phosphate	2.84
Salt	10.79
Black Pepper	2.84
Pepper [a]	4.26
Onion Powder	1.42
Garlic Powder	1.42
Water	454

[a]Treatment 1 = Durkee Six Pepper Blend; Treatment 2 = red pepper.

Table 2: Least square means showing consumer (n = 64) difference between Treatment 1 and Treatment 2 for boneless skinless chicken breast halves

	Treatment	
	1 [a]	2 [b]
Tenderness [c]	1.79[e]	1.50[e]
Juiciness [c]	1.88[e]	1.59[e]
Flavor [c]	2.11[e]	1.55[f]
Appearance [c]	1.72[e]	1.35[f]
Overall Liking [c]	2.14[e]	1.50[f]
Likelihood to Buy [d]	1.98[e]	1.45[f]

[a]Treatment 1 = Durkee Six Pepper Blend.
[b]Treatment 2 = Red pepper.
[c]1 = like extremely; 6 = dislike extremely.
[d]1 = definitely would buy; 5 = definitely would not buy.
[e,f]Least square means within a row with different superscripts differ ($P < 0.05$).

a variation of that product. Even though Treatment 2 was preferred ($P < 0.05$) by the consumers, they still were likely to by both products (Table 2). For this geographical area (southwest United States), the preference of the consumers were ideal because they consume hotter origin food than people of the northeast; therefore, the preference of consumers in the northern region could be different from the southern United States. Marinating not only increases tenderness and juiciness as discussed in Carr et al. (2004), but also enhances flavor and overall liking whether the product is marinated by immersing or injecting as previously stated in Vote et al. (2000) and Hashim et al. (1999).

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CONSUMER ACCEPTANCE OF A JALAPENO GERMAN SAUSAGE UTILIZING A DEHYDRATED JALAPENO PRODUCT

Heather B. Rogers and Mandy A. Carr

ABSTRACT

Three different treatments of pork jalapeño German sausage were used in a consumer taste panel. The control used was the Angelo State University Meat Laboratory's Meat Market jalapeño German sausage (made using fresh jalapeños). Using a dehydrated jalapeño product the two other treatments were produced (a normal ratio of dehydrated jalapeño to fresh pork of 8 oz to 100 lbs, the other a hot version using a 12 oz to 100 lbs ratio. By using a dehydrated product rather than a fresh jalapeño, it may be possible to produce a more uniformly flavored sausage as fresh jalapeños can vary in flavor intensity and quality. The consumer panel consisted of 50 visitors to the meat laboratory which evaluated each treatment on texture, juiciness, flavor, overall liking, and likelihood to purchase the product. No significance difference was found among the treatments and tested factors, except juiciness. The dehydrated treatments were marked as juicier than the control treatment. Though noted as a juicier product, consumers did not indicate they would be more likely to purchase any treatment over the other as all were liked very much.

INTRODUCTION

The current value-added meat category is "exploding" as modern processors are attempting to create new demographic and flavor niches (Tompkins, 2005). The Latino population is the fastest growing in the nation, and this has resulted in new consumer desires that have not previously been explored in the meat industry. Additionally, ready-to-eat and case-ready products have increased to accommodate the fast-paced activity of consumers' daily lives. For example, fully cooked, ready-to-eat sausages made by the manufacturer require no additional cooking, but the product is usually reheated before serving to best appease consumer palatability (Gregerson, 2005). Though today's consumers are seeking easily prepared items, they are also favoring a more traditional or "old world" flavor than before, and sausages, more than ever, are "seeing more variation" (White, 2004). To best understand the consumers' needs, many companies host consumer taste panels to assure their products meet consumer needs and specifications. A mass product survey conducted by *Meat Marketing and Technology* included hot dogs, bacon, deli meat and dinner sausage and a variety of factors were tested on each product. In the dinner sausage panel, it was found that consumers desire less preparation time for the commonly "time-strapped" family (Silver, 2005). Yet according to Paul Stoffregen, Vice President of Sara Lee's Hillshire Farm, sausage must also have "great taste or people won't buy the product" (Silver, 2005). Therefore, the objective of this study was to produce a consumer accepted jalapeño German sausage made with a dehydrated jalapeño product to be tested and marketed at the Angelo State University Meat Market. The dehydrated product is thought to provide the most uniformly flavored product since

fresh jalapeños vary in both flavor intensity and quality.

MATERIALS & METHODS

According to Mr. Pete Brown, A.C. Legg, Inc. Research and Development Coordinator, the normal ratio of dehydrated jalapeño to pork trim is 8 oz to 100 lbs. However, it was decided that local customers could prefer a hotter flavor as well. Thus, another ratio was made using 12 oz. of the dehydrated jalapeño to 100 lbs. of pork trim. Additionally, the dehydrated jalapeños were added to the formulated amount of water to be incorporated into the batter, plus 10 percent. This was to be done approximately 10 min prior to adding to the batter. Rehydration of the jalapeños prior to adding to the batter is necessary to ensure quality of the final product as any remaining dehydrated jalapeños could result in tears in the casings or an unpleasant taste.

The jalapeño German sausage was produced in the Angelo State University Meat Laboratory. The ground pork was separated into 3 – 10 lb batches and each batch received a different type of jalapeño treatment. The ASU Jalapeño German sausage formulation (USDA approved formulation and label) was the control as it had been shown as acceptable to consumers based on the high purchase rate of the Meat Lab's Retail Meat Market. All the pork was ground first through a coarse grinder plate, and then immediately through a fine grinder plate. For the control batch, the ground pork was mixed first with the water, seasonings, cure ingredient (prague powder), and fresh chopped jalapeños for approximately 5 min. For the treatments receiving the dehydrated jalapeño product, the formulated water was added to the designated ratio of dehydrated jalapeños plus 10%. Then the mixture was allowed to stand for 10 min so rehydration was completed before mixing. The remaining procedure was similar to the control product.

All treatments were stuffed into natural pork intestine casings by the vacuum stuffer. The sausage was linked in 1 lb increments. Next, the links were labeled by treatment, draped over the smoke rods at linkage points, and placed in the smokehouse with a temperature probe inserted into a link of each treatment. Once an internal temperature of 160ºF was reached by all temperature probes, the smoke and heat was turned off and a cold water shower applied for 3 min to cool the product. The final product was chilled to less than 40°F, then packaged, labeled by treatment, and frozen (-20°F).

A consumer sensory panel was conducted testing all three treatments. At sampling time, the product was thawed for 48 h at 35^{o}F. The links were grilled on a gas grill until an internal temperature of 160^{o}F was reached. Then each link was cut into 0.5 in. slices and placed in sample warming pans until sampled. The panel consisted of 50 individuals who evaluated each treatment on texture, juiciness, flavor, overall liking, and likelihood to purchase the sausage. Demographic data was also collected from each consumer which included ethnicity, household income, age, marital status, and gender.

RESULTS & DISCUSSION

Except for juiciness, no significance difference was found among the treatments based on the factors evaluated by the consumer panelists. The dehydrated treatments were juicier than the control treatment ($P < 0.05$). However, though noted as a juicier

Table 1. Consumer sensory responses to three versions of a pork jalapeño German sausage

Characteristic	Control	8[y]	12[z]
Texture [x]	1.97[a]	1.95[a]	2.13[a]
Juiciness [x]	2.29[a]	1.81[b]	1.82[b]
Flavor [x]	1.95[a]	2.20[a]	2.04[a]
Overall Liking [x]	2.00[a]	2.24[a]	2.00[a]
Likelihood to Buy [x]	2.10[a]	2.18[a]	2.06[a]

[a,b] Means within a row with different superscripts differ ($P < 0.05$).
[x] 1 = like extremely; 6 = dislike extremely.
[y] 8 oz dehydrated jalapeno to 100 lbs of pork.
[z] 12 oz dehydrated jalapeno to 100 lbs of pork.

product, consumers did not indicate any difference between the three in both overall liking and likelihood to purchase one of the sausages made with the dehydrated jalapeño.

With no significant difference found between the treatments and tested factors, except juiciness which was in favor of the dehydrated treatments, it is possible for the ASU Meat Market to use the dehydrated jalapeño for integration in the ASU jalapeño German sausage. This will allow for a more uniformly consistent product in terms of the flavor intensity and jalapeño quality as the panelists found no difference in overall preference or likelihood to purchase one of the sausages made with the dehydrated jalapeño.

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A STUDY OF ELECTROCOAGULATION TREATMENT OF BEEF HARVEST WASTEWATER

Matthew Dahlberg, Rod L. Reed, Mandy A. Carr, Ned Strenth, David L. Cocke, and Paul Morkovsky

ABSTRACT

Electrocoagulation was evaluated for reducing biochemical oxygen demand (BOD), nitrogen (N), themotolerant Escherichia coli (E. coli), electrical conductivity (EC), and pH change in beef harvest facility wastewater. Twelve 8 L untreated samples were collected from Lone Star Beef Processors in San Angelo, Texas during May and June 2005. Electrical conductivity and pH were measured prior to sub-sampling into four, 2 L samples. Samples were then assigned to one of four treatments: control (NT), treatment A, treatment B, and treatment C. Samples were pumped through the reactor with treatment assigned to different plate configurations. After completing each treatment, pH and electrical conductivity were measured, and analysis for BOD, N and thermotolerant E. coli conducted. Results show electrocoagulation treatment of beef harvest facility wastewater did not ($P > 0.05$) lower BOD, but reduced ($P < 0.05$) thermotolerant E. coli, N, and electrical conductivity, while pH increased ($P < 0.05$).

INTRODUCTION

Discharge of wastewater from meat processing facilities has generated concerns about its impact on the environment. On September 2004, the United States Environmental Protection Agency (US EPA) revised the Clean Water Act Effluent Limitation Guidelines and New Source Performance Standards for meat and poultry processing facilities. The intent is to improve water quality by reducing discharge of conventional pollutants, such as BOD, thermotolerant E. coli, and total N. Each of these effluents negatively affects the environment. According to Khan et al. (1998), the BOD test provides the best estimate of the reactivity of contaminates. The presence of E. coli has been considered a specific indicator of fecal contamination and may indicate the presence of other pathogenic bacteria (Elmund et al., 1999). Increases in electrical conductivity, according to Cousins and Ganczarczyk (1998), may cause a decrease in substrate utilization rates by floc-forming bacteria resulting in increased biomass concentration. Floc-forming bacteria must form properly in order to stabilize organic waste. High N inputs, according to Jabro et al. (2001), may contribute to increases in nitrate levels in water supplies. High N levels may lead to eutrophication of surface waters as well as being toxic to aquatic life and the public.

The objective of this study was to determine the suitability of electrocoagulation for treating beef harvest facility wastewater with three different charged plate configurations, to reduce contaminates (BOD, total N, thermotolerant E. coli).

METHODS AND MATERIALS

Twelve wastewater samples were collected from a wastewater line discharging into an aerobic lagoon at Lone Star Beef Processors located in San Angelo, Texas. A minimum of 8 L was taken on each collection date from May

18, 2005 through June 22, 2005. Sample pH (MP120, Mettler, Schwerzenbach, Switzerland) and EC (B-173, Spectrum Technologies Inc. Plainfield, IL.) measurements were taken from the initial 8 L sample prior to subsampling into four, 2 L samples. Wastewater samples were pumped through a benchtop electrocoagulation reactor developed by Kaselco (Shiner, TX) with three of the 2 L samples subjected to a different treatment. The remaining sample for each date was tested without treatment, and served as the control group (NT). The reactor was designed for adjusting negative and positive plate charges in order to apply three different treatments. Treatments (A, B, C) represented the different plate charge configuration treatments applied. After treatment, pH and EC measurements were taken again. Each sample was then filtered through a coffee filter to remove suspended solids and tested for BOD, thermotolerant E. coli, and total N. Method 1103.1 (US EPA, 2002) was used to quantify thermotolerant E. coli. Total N was determined using method 351.3 (US EPA, 1983). Method 5210 (APHA, 1997) was used to determine BOD levels.

RESULTS AND DISCUSSION

Biochemical oxygen demand

Biochemical oxygen demand levels for treatment groups did not differ ($P = 0.209$) from the NT group (Table 1). These results differ from those found by Panizza and Cerisola (2004) where chemical oxygen demand (COD) levels were lowered in vegetable tannery wastewater from a range of 2000 – 20000 mg/L to a mean of 2193 mg/L ($P < 0.0001$). However, COD analysis measures oxygen uptake from inorganic materials as well as biological uptake, and would be expected to be similar, or higher than BOD levels on the same sample.

Thermotolerant *Escherichia coli*

Treatments A, B, and C, lowered thermotolerant E. coli counts ($P < 0.0001$) when compared to the non-treatment group (Fig. 1). Treatment A had the greatest ($P > 0.05$) effect with a mean level of 1.85×106 cfu/100 ml, an 80% reduction of E. coli. Treatments B and C reduced E. coli levels by 64% and 76%, respectively. These results agree with those found by Skjelhaugen and Donantoni (1998), which showed a 2-log reduction per gram of raw slurry for thermotolerant coliform.

Total nitrogen

Total N levels were reduced ($P < 0.0001$) for each treatment when compared to the control group (Table 3). Treatments were similar with no significant differences between the treatment groups. These results are in agreement with those of Panizza and Cerisola (2004) where ammonia levels were eliminated from vegetable tannery wastewater.

Electrical conductivity

Electrical conductivity values were lower ($P < 0.05$) for each of the three treatments compared to NT. Treatment A had the greatest effect with a mean level of 4.53 ds/cm^2, an 11% reduction. Treatment B was similar to treatments A and C with a mean level of 4.69 ds/cm^2 an 8% reduction from NT. Treatment C had the least effect on EC with a mean level of 4.77 ds/cm^2, a 6% reduction.

pH

Each treatment ($P < 0.0001$) increased pH levels with treatment A having the greatest effect (mean value 8.74) as shown by Table 1. Treatments B and C had similar effects on pH with mean values of 8.04 and 8.07 respectively. This

resulted in a 20% increase in pH for treatments B and C. Sample pH levels also treatment A and a 10% increase for

Table 1. Chemical characteristics of beef harvest facility wastewater following electrocoagulation.

	Treatment				
Parameter	NT	A	B	C	Mean
BOD (mg/L)	398	367	373	373	378
Total N (mg/L)	138.0 a	78.2 b	80.2 b	76.2 b	93.1
EC (dS/cm2)	5.1 a	4.5 c	4.7 bc	4.8 b	4.8
pH	7.3 c	8.8 a	8.0 b	8.1 b	8.0

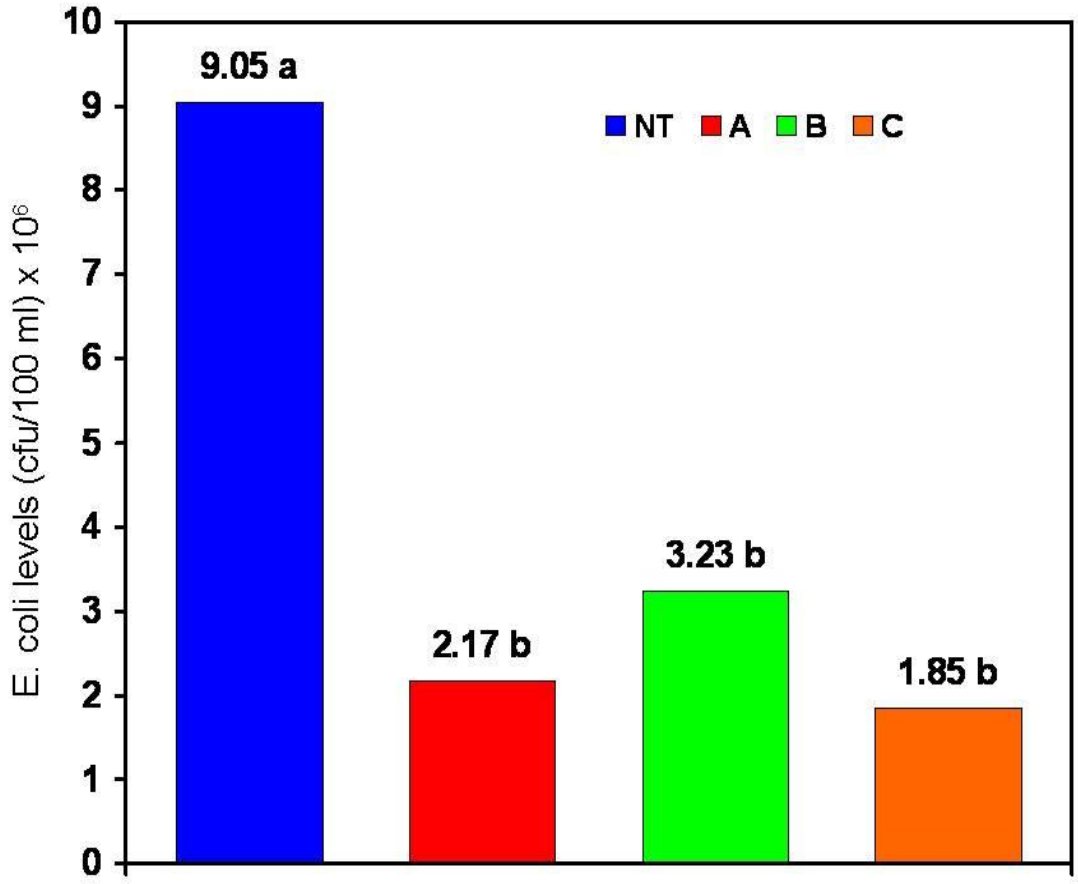

Figure 1. Thermotolerant Escherichia coli levels in beef harvest wastewater following electrocoagulation.

varied ($P < 0.038$) according to collection date.

IMPLICATIONS

The electrocoagulation reactor used in the study has shown some promise of reducing thermal tolerant E. coli, N, and EC while increasing pH levels of samples, without adding chemicals in the process. This may in turn offer a less expensive and effective alternative to the food industry for treating wastewater generated in the harvest process. Treatment A had the greatest overall effect on all effluents. However, BOD reduction was not significant and could require further removal of settleable solids prior to coagulation treatment. Filtration could reduce organic loads and result in a more effective treatment. The results from this study may also indicate that electrocoagulation is more effective for treating inorganic materials in wastewater. Results in this study had significant differences by collection date for each category of effluent. These results may indicate variations that occur in the day to day production process of one beef harvest facility, and effluents for other facilities may also differ from this production process.

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EVALUATION OF INEDIBLE EGG POWDER AS A NUTRIENT SOURCE FOR SEEDLESS WATERMELONS

Rod Reed

Introduction

The demand and popularity of watermelon (*Citrullus lanatus*) is increasing in the United States as evidenced by the 33% increase in per capita consumption from 1980-1995 (USDA Economic Research Service, 1998). In the United States, production of watermelon makes up a considerable portion of agricultural income in southern states. In 2004, the United States as a whole had 141,200 acres of land in watermelon cultivation, with production topping 3.6 billion pounds of saleable fruit for a combined value of over $313 million dollars (USDA-NASS). Texas alone, in 2004, had 27,500 acres of watermelon that produced over 605 million pounds of fruit with a value of over $60 million dollars.

Currently, watermelon growers are shifting from seeded (diploid) to seedless (triploid) watermelon production due to increased consumer demand and a greater economic profit obtained from growing seedless watermelon (Karst, 1990; Marr and Gast, 1991). Between 1992 and 1999 there was a 17% increase in household purchases of seedless watermelon (The Packer, 1999). Seedless watermelons are valued for their smaller size, as well as their apparent lack of seeds. Seedless watermelons are not actually seedless, but contain small, immature seeds that can easily be eaten along with the fruit.

Seedless watermelons require special cultural practices to produce adequate yields as the plants do not produce sufficient pollen to fertilize female flowers (Rhodes et al., 1997). Pollinizers must be interplanted with the seedless cultivar as a source of pollen (Rubatzky and Yamaguchi, 1997). The production of seedless watermelons is also made more expensive by the price of seeds. Hybrid triploid seeds are 60 times more expensive than open pollinated diploid seeds and are more difficult to germinate and successfully transplant into fields. The seeded watermelons planted alongside the seedless watermelons serve dual purposes as pollinators as well as producing saleable seeded watermelons.

The demand for organic produce is on the rise in the United States, as consumers become more health conscious. Thereby the need for an effective organic fertilizer arises. Inedible egg powder may fit that niche. Inedible egg product is defined as any egg meeting the following definitions: black rots, yellow rots, mixed rots (addled eggs), sour eggs, eggs with green whites, eggs with stuck yolks, moldy eggs, musty eggs, eggs showing blood rings, and eggs containing embryo chicks (United States Code). Inedible egg powder is produced by spray drying the liquid of the mixed eggs and then grinding it into a powder. Inedible egg powder is not acceptable for human consumption, however it is suitable as an additive in animal feeds. Apart from eggs culled prior to the breaking of eggs for commercial purposes, inedible egg liquid comprises a sizeable portion of total egg products. In 2004 there were 219,211,000 pounds of inedible liquid egg produced (USDA-NASS). Inedible egg powder ranges from 50-58% protein, which translates to roughly 8-9% nitrogen. Being a natural product, it should be highly biodegradable and available to plants for uptake and utilization for

growth. Inedible egg powder can be expensive when compared to inorganic nitrogen fertilizers, but the cost of nitrogen fertilizers is rising with the increased costs of fuel and energy. However, the additional cost of inedible egg powder as a fertilizer may be an economically justifiable and suitable alternative in an organic production setting due to increased returns on organic produce. Therefore the objective of this study was to determine the effectiveness of four fertilizers, two organic (inedible egg powder and cottonseed meal) and two inorganic (18-6-12-4 and 33-0-0-11), on the production and quality characteristics of seedless 'TriX 313' watermelons.

MATERIALS AND METHODS

Sixteen test plots were prepared at the Angelo State University Management, Instruction and Research Center north of San Angelo, Texas. The plots were 5 foot by 12 foot each (six plants per plot, spaced 2 foot apart); the soil type was an Angelo clay loam (fine, mixed, thermic) with a 0-1% slope. Four treatments were randomly assigned to plots in a Latin square design. The four treatments (Table 1) included inedible egg powder (Rose Acre Farms, Inc., Chicago, Illinois), cottonseed meal (Palmer Feed and Supply, Inc., San Angelo, Texas), Uripels 33-0-0-11 fertilizer (American Plant Food Corp., Fort Worth, Texas), and Pursell's Sta-Green 18-6-12-4 fertilizer (Pursell Industries, Sylacauga, Alabama). All fertilizers were broadcast onto the plots (equivalent to 100 lb of nitrogen per acre) and incorporated into the soil to a depth of one inch with a garden rake. Following treatment application, watermelons were transplanted and irrigated with a dilute starter fertilizer solution. The transplants for the study were hybrid triploid TriX 313 (Speedling, Inc., Alamo, Texas) and the pollinator transplants were 'Jamboree' (Speedling, Inc., Alamo, Texas). The plants were transplanted into test plots on June 1, 2006. Six TriX 313 plants were planted in each plot, with the four central plants serving as the test plants in each individual plot. The test plots were surrounded by a border of Jamboree and AllSweet (Abbott and Cobb, Inc., Feasterville, Pennsylvania) as pollinators. Drip tape irrigation (Typhoon 636 12.5 F, 24 inch spacing, Netafilm, Tel Aviv, Israel) was installed on June 1, 2006 and plots irrigated once per week to avoid moisture stress. The plants were measured for canopy size on three dates. Measurements were taken point to point across the longest runners of the plant and then width was measured perpendicular from that axis. Each of the four central TriX 313 plants was measured and information recorded. Chlorophyll measurements were taken on seven dates during the growing season using a SPAD 502 chlorophyll meter (Minolta Corp., Osaka, Japan). One leaf from each of the four central plants in each plot was randomly selected and chlorophyll levels measured and recorded.

RESULTS AND DISCUSSION

Our objective of comparing the production and quality of seedless watermelon fertilized with two organic and two synthetic fertilizers was not realized due to feeding damage by white-tailed deer. This damage was unexpected as watermelons had been grown in an adjacent area the previous year with no damage. Attempts were made to minimize damage by placing poultry netting horizontally over the plants. This was effective for part of the growing season

Table 1. Chemical composition of fertilizer materials used to grow TriX 313 seedless watermelons at San Angelo, Texas in 2006.

Treatment	Nutrient			
	N	P_2O_5	K_2O	S
	---------- % ----------			
Inedible egg powder	8.3	2.1	2.1	NA
Cotton seed meal	7.2	2.6	2.3	0.3
Uri-Pels	33	0.0	0.0	11
Pursell's Sta-Green	18	6.0	15	4

and allowed collection of plant size and chlorophyll content data (Tables 2 and 3). However, as the growing season progressed the plant size exceeded the width of the poultry netting and the deer began feeding under the netting and on the portions of the watermelon plants that grew outside of the netting.

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Table 2. Plant size of TriX 313 seedless watermelons grown with four different fertilizer sources at San Angelo, Texas in 2006.

	IEP	CSM	33-0-0-11	18-6-12-4
June 16				
Length (in.)	15.8	14.5	14.4	15.2
Width (in.)	6.6	7.8	7.9	7.3
June 27				
Length	33.8	30.1	32.0	30.2
Width	13.1	18.0	17.4	15.9
July 13				
Length	57.9	53.2	60.7	58.3
Width	22.7	20.2	23.5	20.9

Table 3. Chlorophyll readings of TriX 313 seedless watermelons grown with four different fertilizer sources at San Angelo, Texas in 2006.

Date	IEP	CSM	33-0-0-11	18-6-12-4
June 16	38.6	43.8	38.4	43.1
June 27	46.9	45.8	43.6	49.5
July 6	51.6	43.2	51.8	50.7
July 13	53.6	51.1	50.4	53.4
July 20	54.1	57.9	56.1	57.4
July 27	56.5	56.3	56.7	58.1
August 1	57.1	58.8	61.0	61.7

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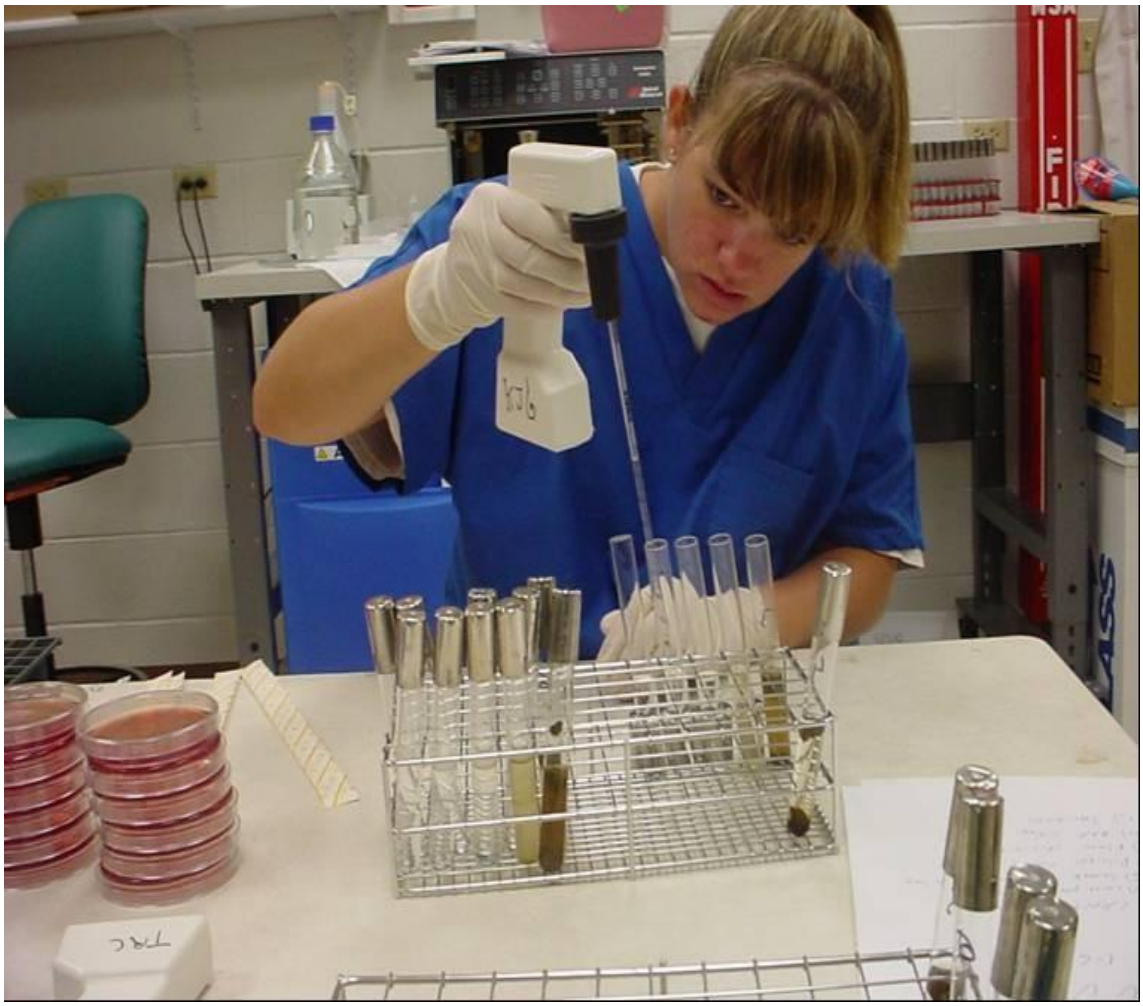

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AGRICULTURE GRADUATES

Bold denotes graduate student

1975
Robert Glenn Burwick (December 1974)
Tom Burson
Ronnie Edington
Alton Everett
Randy Gill
Rebecca Harris
Marcus McCellan
Donald Phelps
Horace B. Walker
Randy Bredemeyer
Thomas Jernigan
Guy Levey
Ricky Marks
Riley Sterling

1976
Bobbie Baldwin, Jr
Debra Beth Barker
Ricky Lane Childress
Warren Fay Dozier
Charles E. Fant
Ronald Edward Halfmann
Daniel Wayne Kujawski
John William Van Court
Donald Joe Wilde
James Carl Williams
Calvin Jackson
Johnny Wayne Todd
Malcolm F. Gerngross
Curtis Ben Cox, Jr.
Larry William Dean
Jimmie Lee Trojcak

1977
Thomas Lee Allen
Richard Ray Collett
William Stephen DeHay
Bernard Fuchs
Ernest Fred Groff
Charles Jackson Hughes
Sidney Truman Johnson
Kevin James May
Mark Louis Shepard
Virgil Neil Conner
Charles Bernard Halfman
Stephen Morris Hinshaw
Steven Hoelscher
James K Kiunga
Jerry Talley Jr.

1978
Paul Daniel Barnhill
Raymond W. Beam
Terry Lynn Blair
Tony Carl Frerich
James Keith Hood
Michael Fred Matthews
Jo Ann Snodgrass
Terry Lynn Stokes
Kenneth Wayne Straw
Jack M. Sykes
Jim William Wright
Danny David Daniels, Jr.
Darrell Gene Meyer
Dale Edward Neagle
Donald Harold Bunch
Vickie Patterson Hillger
John Lloyd Newman
John L. Seaton
Lee Edwin Warren
Galen Ray Weiershausen
Thomas Alton Williamson

1979
Shelia Elaine Allbright
Joe Bass Arnett
Calvin Dee Boatright, Jr.
Debra Ann Clouse
Andy Mike Eubanks
Ronald James Gill
Joel Wayne Holladay
Robert Benjie Jay
Brian Forrest Meeks
Randall Oein Pittman
David Lane Tunmire
Dennis Jay Uherik
Faron Almon Pfeiffer
Joe Don Roach
Tom Heath
Milford Logan
Bill Wilson

1980
Preston Elba Adams
John T. Bassinger
Howard Gene Callison
Mark Winn Dobbins
Dean William Eckert
Steven Neil Glass
David H. Masters, Jr.
Brian John May
Joseph Gregory McReynolds
Charles Richard Bradshaw
Bruce Deere
Michael Garza
Kelly Jean Gully
Brent Heinze
James Alton Kolb
Victor Roy Probandt
Jay Thomas Holstein
Mark Allan Mishnick
Gary Don Stokes
Tandy Sueann Wilmeth
Gary Lee Wilson

1981
Bruce Backland
Steve Cook
Kyle Christopher Hodges
Ricky Machen
Julie Ann McFarlin
Dennis Newton
Charles O'Connell
Brad Pierce
Rodolfo Diaz Ortiz
Elias C. Rodriquez
Pat H. Shannon
Vernon Elliot Sublett
Bernie Wallace
Brenda Kay York
Duane Allan Stryker
Mark Louis Shepard
George Scott
Gerald Glen Risher
Ronald J. Gill
Lee Edwin Warren

1982
Randall Bankhead
Terry Lee Criner
Pat Dryden
David Fuessel
Stephen Kuhlmann
Mary Jean Owens
Danielle Rosser
Patty Dietrich Stokes
Arthur Wayne Striegler
Terry Waller
Michael Scott Wilburn
Mark Wylie Worthington
Robert Charles Surratt
Brian J. May
Milburn Wright, Jr.
Curtis Glenn Childress
Kelley Ann Collins
Craig Demere
Louie Grant Drennen
Timothy Clay McReynolds
Frank Pecina Jr. III
Vaden Aldridge
Stephen Byrns
Faron A. Pfeiffer
Henry Gene Adams, Jr.
Alan Bossenger
Harlan Clay Nance
Ken Roy Pfluger
Paula Kay Saunders
Jeffery Kyle Wright

1983
Mike Barrera
Curtis Boos
Donald Loding Campbell
Dennis Vinson Cumbie
Edward Earwood
Kevin Hale
David Hayden
Joey Henderson, Jr.
Roberto Hernandez, Jr.
Dana Johnson
Johnny Murchison
Roy Musquiz, Jr.
Donald Reeh
Mark Swening
Alfred Vardeman
Brett Alan Williams
Bruce Backlund
Yousef Bengharsa
Will Walter Allison
Carol Cervenka
Mary Ann Kirk
Emily Elizabeth Moll
Barbara Pfieffer
Jack Renfro
Sandra Lynne Stewart
Mustafa Mohamed Mankusa
Randall C. Ward
Gary Lynn Bishop
James Robert Harris
Brad Mund

1984

James Hood
Molly Baskett
Wilburn Baucom
Gideon Cheruiyot
Craig D. Cook
Charles Brett Cypert
Keith Floyd
Lisa Gabier
Danny Gunn
Timothy Fred Hardt
Taylor Dean Hayes
R.D. Hinojosa, III
Vanessa Lusby
Bill Pitman
Eddie Probandt
Bobby Rogers
Dee Ann Smart
Stephen Surratt
Wesley Joseph John Thee
Mike Thomas
Bradley Dean Thompson
James Wilde
Bruce Deere
Robert R. Allen
Greg Browning
Leland Hunt, Jr.
Partick Pearce
Steve Sappington
David Wayne Schofield
Calvin Glenn Steward
Rodney Jay Winn
Gary Dewayne Callaway
Renee Michelle Evans
Rex C. Ewert
Hillie Hunter Hayes
Wesley Zane Hodges
Leland Wayne Key
Daniel Russell Koenig
William C. Kothmann
Roger Woods Lux
David Brent Sherrill
Joe David Sherrod
Todd Wade Swift

1985

Donald Blair
Randall Brown
Jimmy Fontenot
Randall Jenkins
Charlotte Klepac
Scott Porter
Stephen Wayne Reynolds
Pat Thomas
Wilton Weise
Ben Wilde
Darrell James Wilde
Rafael Suarez
Johnny Murchison
Sulaiman Awagi
Jeff Hamilton
Jay Hawkins
Mark Ramirez
Danny Vann
David Bruce Fletcher
Ricard Kelly Gilbert
John Harvey Gronold
Cary Dean Hannsz
Stehpen Scott Mooney
Steven Reece Moore
Royce Lee Pyssen
George William Smith
James Curtis Turk

1986

Thomas Ray Allen, Jr.
William Banner
Scott Lamar Cauthen
Jonama Cox
Joe Branton Day
Carlos Gibbs
Greg Keith Hagel
Lee Strait Hitch
Wayne Carl Hofmann, Jr.
James Walter Keeton
James William Kothmann
Randy Dale Kruse
Mike T. Kyzar
Mark Randall Oates
Clay Yandell
Cary Don Baker
J.W. Carter, II
Jeffrey Duncan
Michael Wayne McDaniel
Wade McMurrary
Kaung-Huei Liu
Stephen Ray Sappington
Jeffery Kyle Wright
Kevin Dale Barron
Carle Max Brandenberger
Stacy Todd Campbell
Eddie Frank Dusek
Kirk Lane Griffin
Gregory Irvin Hohensee
Regan Stuart Kirk
Bonnie Lou Mayer
Joao Livio Norberto
Steven Mark Quade
Eugene Bitner Roberts
Rocky Stewart Vinson

Raymond Roy Walston, Jr.
Jeffrey Craig Williams

1987

Leland J. Hunt
Terry Brent Baucom
James Hubert Bell
Ella Marie Blair
Lonnie Randall Bolf
Jay Donivan Daniel
Samuel D. Fuhlendorf
Bradley Dwayne Fulton
Jeb Brant Henderson
Robert P. Hunter
Courtney Lance McNeely
Kathering Inez Pappas
Fernando Adlolfo Reyes
Darren Ray Richardson
Gregory Ray Schwertner
Maribel Alicia Tarango
Karl Tatsch
Rex Taylor
Roger Tinder
Jerry Don Vinson
Bryan A. Davis
Troy Lennon
Helio Paranagua, Jr.
Jimmy Fontenot
Randall Jenkins
Steve Moore
Bennie Caly Edwards
Jan Hatler
Kraig Peel
Kenny Strube
Tracy Tippett

1988

Steve Kuhlman
Nancy Benson
Scott Christopher Blanton
Kay Carrig
Michael Fanning
David Feldhoff
Karen Frey
Lee Higdon
Jeff Lewis
Wade Menges
Chris McReynolds
Monica Reining
Kathy Thompson
Ken Weidenfeller
Allan West
Cheryl Robinson
Dave Cleavinger
Terry Criner
Larry Herd
Trey Glen Morgan
C.W. Roberts

1989

Deborah Sue Divich
Russell Stevens
Clinton Calk
Browder Graves
Mark Gray
Kelly Griffin
William Mark Harris
Lester Everett Matthews
Kevin Pounds
Joseph Raff
Jacqueline Hermesmeyer
James Glen Miller
Noel Williams
David Carlisle
Amy Teagarden
Roddy C. Gordon II.
Novice Joe Moore
Russell Rogers
Frankie Sablan
Marck Todd Schafer
Barry Smith

1990

Adebanjo Adesoji
David Bohnert
Bill Head
James Horton
Clint Koenig
Kevin Owen
Cody Scott
Troy Seals
Jim Meredith
Larry Herd
Lee Clark
Ronald Gillaspy
Bobby Herrington
Randy Houston
Ed Miller
Britton Lee Roman
Wiley Payne Rudasill
Trent Tankersley
Tom Underwood
Kevin Pfeiffer
Brad Spenrath

1991

Bryan Davis
Lynn Dye
Robert Charles Graff
Mike Harbour

Wendy Holman
Randall McCarty
Wade Menges
Miguel Rendon
Richard Shaver
Daryl Whitworth
Scott Grote
Frank Habecker
Gus Ward
Joe Raff
John Clifford Fisher
John David Laxson
Billy Jay Ledet
Eldon Todd Love
Kevin P. Przilas
Kristi Lynn Stone
Todd Swift*

1992
Albert L. Booky
Clinton Calk
Barry Lee Cooper
Cody Burk Scott
Justin Amerine
Shawn Burns
Jeffrey William Cowan
Roy Kevin Downey
Sharilyn Sue Friesen
Justin Henefey
Jamie Carole Inman
Brett Johnson
Chad Seward
Robyn Sims
Timothy Smith
James Sullivan
William Alan Head
Melissa Bollinger
Tim Lust
Keith Randall Shaffer
John David Whipple
Pammy Lynn Millican
Timothy Sean Phy
Todd Rossington
Debra Rozell
Todd Schafer

1993
Bryan Davis
James Weldon Faught
Randy Alan Gartman
Linda B. Naranjo
Steven Don Parker
Robert Pritz
Nikki Dawn Ramsey
Virginia Shannon Riley
Belinda Rivera
Kelly James Sanders
Mitchell Elton Wilmeth
Chad Coburn
Chris George
Kip Giles
Cody Hill
Kevin Shane Kelton
Kelly Gully
David Laxson
Jason Lee Bannowsky
Michael Brent Crawford
Robbie Glenn Eckhoff
Charles Estanol
Dawn Alicia Kleiber
James Clayton Richards
Dale Anthony Schwarts
Terri Bibb Webber

1994
Amber Bickham
Terry Blair
David Bohnert
Marvin Dale Dunlap
Russell Rogers
Shannon Bennie Bannowsky
Michael T. Billingsley
Donna Cates
Melvin R. Davis
Darrell Dusek
William Todd Friend
Charles R. Hollingsworth
Gilbert Horton
Jason Victor Jones
Alyson Kay McDonald
Daniel Park
Micheal Salisbury
Roxanna Kate Schwinge
Allie Snider
Walker Walston
Keith Shaffer
Thomas Bryan
Olen Burditt
Jeff Chisum
Janet Cox
Thomas Hughes
Jeremy Don McCollom
Michael Moore
Martin Weatherbee
Ed Miller
Glen Allan Phillips
Brain Harwell
Rebecca Haschke
Winston Herndon
Justin Marschall

Elizabeth McFadin
Allen Russell Morgan
Stacy Lane Morris
Chad Sims
Travis Kent Wier

1995

Marty Gibbs
Kelly Sanders
Katherine Allison
Ross Benson
Malcom Boger
Jimmy Caughron
Wade Cypert
Blain Ferris
Ramiro Guzman
Brian Hill
Brantely Hoelscher
Eddie Onofre
Fulton Pizzani
Rowdy Rea
Scott Smetana
Faron Sultemier
Make Zuniga III
Chad Coburn
Mikel Harbour
Homer Lee Higdon III
Nancy Law
Kimberly Ann Ball
Shelly Summerour
Philip Carter
Ross Stultz
Shelly Frazier Best
Kevin Duke
David Foster
Walden Hillert
Todd Holbrooks
Scott Hohensee
Thomas Franklin Kelso
Tara Mallett
James Murdoch
David Hershel White
Katerine Wurster

1996

Gibert Horton
Wade Armke
Michelle Behrends
Billy Belew
Cain Cline
Jill Dice
Steven Hise
Thi Hoang Oanh Hoang
Billy Mac Howe III
Pam James
Shawn Nanny
Jeffrey Osbourn
Jody Osbourn
Brad Roeder
Cody Schoenfeld
Gwendolyn Sue Taff
Kathrine Valdez
Dan Vestal
Richelle Renee Wilson
Doug Bawcom
Bryan Bendele
Todd Broncy
Trey Garmon
Pascual Hernandez
Sara Lewis
Abel Robles
Tim Sims
James Steen
Jason L. Denman
Christopher S. Herzog
John David Isenhower
Brook Dowell Matthews
Richard Minzenmayer
Mike Salisbury
Brady Weishuhn
Sandi Zimmerman

1997

Kim Ball
George Trey Poage
Rowdy Rea
Ronnie Brewer
Kim Cox
Eddie Hall
Brandon Heiser
Bridget Mansell
Jerry McGinnis
Dac Pennick
Octavio Ramos
Christy Strube
Jodie Uptergrove
Shawn Uptergrove
Jeremy Blain Myers
Amy J. Pilmer
Peggy Simpson
John Barfield
Kevin Kuhlmann
Bennett Tate Thoreson
Whitney Whitworth
Rebecca Young

1998

Justin Alexander
Wade Armke
Reace Bennett

Bryan Campbell
Richie Griffin
Lane Hughes
Pamela James
Bridget Jones
Steven Jost
Charles Kneuper
Richard Lepard
Leesha Ligon
Jason McCoy
Rachel Pentecost
Andria Perales
Jennifer Rose
Geoffrey Scott
Adam Clay Warren
Casey White
William Wood
Jason Frost
Jeremy Brandon Hartgrove
Jay Holt
Robert Paul Law
Wesley Whitehead
Brain Shane Atzger
Parrish Braden
Rusty Fleeman
Daniel Kuntz
Thomas Randall Rakowitz
Stephen Wade

1999

Jennifer Bedell
William D. Burns
M'Liss Burrier
Amy Coburn
Kim Cox
Dewey Alan Drennan
Bronson Gobert
Eddie Hall
Dale Ashton Harris
Brandon Heiser
Brantely Heiser
Tessie Ingram
Shelby Johnston
Chris Lupton
Leslie Moczygemba
Fred Reyna
Karalina Rigsby
Anthony Sanchez
Kristina Schulze
Peggy Simpson
David Sirmons
Shelly Smith
Julie Smithwick
David Stone
Wade Travis Tellinghuisen
Juan Vasquez
Clint Warren
Justin Weishuhn
Laurie Weishuhn
Karee May Wiggins
Jeriann Williams
Ashley Wilson
Grady Wilson
Brandon Zesch
Rhea Allen
Clint Matt Culp
Sarah Fitzgerald
Ronald Heineman
Ladd Hughes
Pamela Jetton
Kevin Shane Kelton
Charles Seidensticker
Terry Sirmons
Whitney Whitworth
Justin Clark
Sherry Hall
Mark Martinez
Todd O'Neil
Robert Allen Parry
Byron Wayne Pfeifer
Robert Phillips
Monica Swenson
Michael Weckel
Cynthia Whitehead

2000

Maria Anzaldua
Brandon Asbill
Jamie Bass
Andrew Boomer
Garry Branham
Bret Breitenkamp
Bill Burnes
Cory Carroll
David Bradley Cook
DeAnna Crain
Dee Dusek
Kelly Edwards
Jason Frost
Rachel Frost
Brandon Green
Richard Griffin
Beverly Gully
Tom Guthrie
Devin Hoover
Caleb Kattner
Charles Kneuper
Stacey Kotrla
Justin Lampier
David Lytle

Jerry McGinnis
Zeno McMillan
Alvaro Ruiz
Robert Ross Sims
Robert Steakley
Jared Taylor
Wynne Whiteworth
Lee Brinegar
Justin Douglas Dunlap
Kelly Hart
Matt McMillan
Kari Ashcraft
Amanda Browder
Brock Fry
Jana Jackson
Quinn Johnston
Caylie McClure
Martin Schuh
Stephen Wade
Charlie Wakefield
Chad Zibilski

2001
Jesus Becerra
Blake Belcher
Russell Dean Black
Joshua Blanek
Ben Brandon Brooks
Christopher Carey
Justin Collins
Marshall Davidson
Curry Dawson
Susan English
Heidi Ertresvaag
Caitlyn Felder
Becca Ferguson
Jeff Fiedler
Sarah Fitzgerald
W.C. Foster
Curtis L. Garrett
Briana E. Harbaugh
Tami Harris
Ladd S. Hughes
Jon Jennings
Will Kiker
Haley Jo Knutson
Eli Ornelas
Kari Pierce
Laura Rush
David Sirmons
Craig Thomas
Jake Wagner
G.W. Yandle
Andy M. Laughlin
James William Loveday
Deana L. Moore
Jason William Stewart
Jeffrey Wheeler
Justin Will Avery
Jeffrey Lane Berry
Corrie Maria Canava
Chad R. Ellis
Brian Faris
Patrick Fowlkes
Casey Ray Hayes
Jennifer Ann Heard
Shy L. Middleton
Fred Reyna
Gary Alan Witt

2002
Casey Alexander
Garry Branham
Loree Branham
Maria Terrie Carr
Cory Carroll
Robert Cook
Justin Corzine
Bobby Deeds
Robert Diaz
Wayne Trey Dunson
Amy Heathcott
Jed Hruska
Haden Keyser
Brandon Payne
Fabian Rodriguez
Eric Ross
Alicia Simpson
Robert Steakley
Jeff White
Ty Williams
Telitha Winge
Jason E. Entzminger
Rebecca Lynne Hill
Tessie Irene Ingram
Kristopher Kaufmann
Charles H. Wakefield
Lue F. Arn III
Bobbi Lee Blanek
Jessica Sue Boesen
Jason Brooks
John Lee Carr
Casey Dawn Carroll
Jessica Cobos
Melissa A. Cone
Derric Dustin Crowe
Justin Matthew Duyck
James Robert Ellison
Cameron Wade Everton
Richard H. Fohn

Brock Fry
Brandi Lane Loftis
Fernando Martinez
Heidi Erin McIntyre
Norberto Mendoza, Jr.
Jerrod K. Pitcock
Joe Martin Self, Jr.
Scott Jeffery Talley
Krista Renee Tydlaska
Cassidy Watson
Wynne Rae Whitworth
Dara Alyssa Wilde
John Zertuche

2003
Jessica Renee Atchley
James Ray Bilbrey, Jr.
Kevin Jacob Drennan
Brent J. Dugas
Daniel C. Dusek
William C. Foster
Jessica Y. Gomez
Phoebe Ann Harrell
Justin Waid Jackson
Will Kiker
Haley Jo Knutson
Lacy Darlene Mercer
Christopher Merren
Jonathan Wayne Meurin
Michael J. Pentecost
David D. Powell
Mark Ray Sheets
Benjamin D. Taylor
Carrie A. Taylor
Lena Alison Williams
Spencer W. Wyatt
Paul G. Yandle
Lessa Ann Bullock
James M. Clark
Andrew M. Hart
Sean M. Kendrick
Kristy Ann Melton
James Paul Skipworth
Sonya M. Washington
Audrey Akers
Courtney Allen
Leslie Ann Fangman
Dustin Gragg
Mary Elizabeth Guerra
Lauren Hahn
Jeremy Haynes
John Allan Henkhaus
Bryan Jennings
Jessica Kiker
Jason McDaniel
Trenton Stephens
Brian Stevens
Leticia Stogner
Cody York

2004
Leslie Alexander
Levi Babb
William Travis Bond
Michael Burrows
Shannon Counts
Mia Dues
Kyle Ellis
Krystal Farmer
Blake Gentry
Jenai Gill
Scarlett Lampier
John Henry Leifeste
Cathleen Moore
Chris Moore
Elliott Parks
Jamin Phipps
Kimberly Terrell
Jessica Williams
Loree Branham
Robert Cook
Daniel de Carvalho
Bobby Deeds
Wayne Dunson
Shy L. Middleton
Brandon Payne
Marc Tucker
Daniel Woolley
Jon Austin
John Craig
Tara Basse
Ned Dunbar
Jonathan Ellison
Nathaniel McMillan
Michael Lackey
Norberto Mendoza

2005
Jon Calcote
Kevin Corzine
Jarrod Cook
Rodney Henderson
Cliff Kinnibrugh
Clint LeMay
Teresa Lovett
Rayle Taylor (Self)
Kayla Niehues
Corey Owens
Andrea Payan
Chase Ratliff

Andy Sandbothe
Levi Wilhite
Andrea Shields
Brandon Asbill
Will Hartnett
John Kellermeier
Michael Thornton
Lauren Hahn
Joe Self
Tammy Vretis
Tyler Bybee
Ross Copeland
Blake Franke
Aaron Hart
Jeremy Hasty
Tabitha Lloyd
Darby Makloski
Morgan McCutchen
Alfredo Munoz
Thomas Parks
Dustin Ratliff
Dixie Simpson
Heath Stoerner
Shelley Talley
Cole Wadsworth
Trevor Watson
Ty Wheeler
Billy Krasowsky
Jessica Cobos
Matthew Dahlberg
Curry Dawson
Steven Sturtz
Lacy Vinson

2006
Jon Bean
Cody Bundick
Jessica Burrus
Crystal Clayton
Destiny Dartez
Travis Downs
Clay Evans
Luke Everett
Dusty Gressett
Trey Hale
Justin Harlin
Jacob Harrison
Chance Hundley
Samson Jackson
Cole Jacoby
Kale Jones
Jake Johnson
Dustin Knowles
Drew McEachern
John McEachern
Matthew Menchaca
Douglas Miller
Anthony Munoz
Kasey Murphy
Bartley Murray
Blake Payne
Travis Pitcock
Braden Riha
William Ritter
Heather Rogers
Mario Saenz, Jr.
Thomas Schenkel
Sam Schiwart
Elizabeth Schulze
Victor Schulze
Chase Settle
Anthony Soliz
Jamie Steen
Elizabeth Stubsjoen
Shelley Talley
Aaron Taylor
Josh Thweatt
Justin Trimble
Rodney Weiser
Ryan Wells
Cole Wilkins
Evan Wilson
Kyle Youngblood
Blake Coates
Tim Dietz
Ned Dunbar
Shelley Gunter
Andrea Payan
Jamin Phipps
Natalie Sato
Don Skiles
Dustin Yates