AN ABSTRACT OF THE THESIS OF

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Dr. Timothy DelCurto

A survey was conducted during the summer (July-mid September) of 1991 to evaluate the nutritional quality of grass seed residues. Grass species sampled included tall fescue (*Festuca arundinacea* Schreb.), orchardgrass (*Dactylis glomerata* L.), perennial ryegrass (*Lolium perenne* L.), annual ryegrass (*Lolium multiforum*) and bentgrass (*Agrostis* L.). Perennial ryegrass composed 46.3% of the total samples (136 samples), followed by tall fescue at 41.5% (122 samples), bentgrass at 8.8% (26 samples) and all other grasses at 3.4%. Baled straw was core-sampled using a forage sampler. Nutritional analyses performed on the samples include CP, ADIN, ADF, NDF, and in vitro digestibility. High pressure liquid chromatography (HPLC) analysis was also conducted on the tall fescue and perennial ryegrass samples to measure alkaloid (ergovaline) content. Bentgrass had a lower percentage ADF (37.8%) as compared to the other four species ($P<.05$). Orchardgrass and annual ryegrass had similar ADF components ($P>.05$). Tall fescue, bentgrass and perennial ryegrass had higher CP levels as compared to orchardgrass and annual ryegrass ($p<.05$). Bentgrass was significantly lower (63.7%) and annual ryegrass significantly higher (72.8%) in NDF as compared to the other grasses ($P<.05$). Perennial ryegrass and bentgrass had the highest in vitro dry matter digestibilities (55.5% and 55.0%, respectfully) compared to annual rye (51.1%) and orchardgrass (48.7%), with tall fescue (53.9%) being intermediate ($P<.05$). Mean ergovaline concentrations for tall fescue and perennial ryegrass were 86 parts per billion (ppb) and 214 ppb, respectively. Of the tall fescue fields sampled, 14% had ergovaline levels greater than 200 ppb while 42% of the perennial ryegrass contained ergovaline levels greater than 200 ppb. In this survey,

bentgrass, perennial ryegrass and tall fescue had chemical compositions which indicate higher nutritional quality compared to orchardgrass and annual ryegrass. When properly supplemented, the residues from these three species appear adequate for winter-feeding of spring-calving beef cattle.

In the following winter of 1991-92, two studies were conducted to evaluate the effect of alkaloid concentration in feeding high endopyte infected tall fescue straw (variety Titan). In Exp. 1, 16 Hereford x Angus ruminally-cannulated steers (avg wt = 370 kg) were blocked by age and weight and, within weight blocks, randomly assigned to one of four treatments: 1) 100% Titan, 2) 67% Titan-33% Bonanza, 3) 33% Titan-67% Bonanza and 4) 100% Bonanaza. High pressure liquid chromatography (HPLC) analysis for ergovaline on the straw measured 475 ppb for Titan and 0 ppb for Bonanza. As a result, the basal diets of straw for treatments one through four, contained 475, 317, 158 and 0 ppb ergovaline, respectively. This 36 d digestion study involved a 21 d adaptation period, 7 d intake period, 6 d of total fecal collections, a one d rumen profile and one d of rumen evacuations, respectively. Total feed intakes for the diets, in order, were 7.9, 7.4, 7.5 and 7.9 kg and had apparent DMD ranging from 46.0 to 48.8 and NDF digestibilities from 42.8 to 44.3 ($P>.10$). Physiological parameters (heart rates, respiration rates, rectal temperatures, ear and tail head skin surface temperatures) were not influenced ($P>.10$) by treatment rations throughout the 36 d study. Blood samples for prolactin (PRL) analysis, obtained once a week at 1300 h, showed a linear decrease in cirulating PRL levels across treatments ($P<.10$). At the conclusion of this study, each steer was injected with 100 *u*g of thyrotropin releasing hormone (TRH) to measure PRL stores in the pituitary. All steers responded to the TRH challenge; the magnitude of response was similar across treatments and not affected by alkaloid levels ($P>.10$). Differences were seen in digesta kinetics, particularly IADF fill and IADF outflow, and attributed to differences in the diets' IADF component rather than alkaloid concentrations. Ruminal pH, ammonia and volatile fatty acids showed no treatment x time interaction when analyzed as a split plot except for proprionate and acetate:proprionate which showed a significant treatment by time interaction ($P<.10$). Both propionate and acetate:propionate ratios displayed significant responses: a quadratic response ($P<.10$) at time 6 and time 12, and a linear response (P<.01) at time 9. In Exp. 2, 84 Hereford x Angus weaner steers (avg wt = 220 kg) were allotted into three weight blocks (heavy, medium and light) and, within weight blocks, randomly assigned to the above treatments for 84 days. Both total DMI and straw DMI in Exp. 2 showed a linear response across treatments (P<.10); intakes increased with decreasing alkaloid levels. However, treatments had no effect on weight gain (avg wt gain = 14 kg, P>.10) and feed efficiency averaged across the entire 84 d feeding period (P>.10).

In conclusion, the endophyte produced alkaloids associated with feeding tall fescue straw in these studies did not cause health problems or reductions in animal performance. However, circulating PRL response to alkaloids did show a decrease in the weekly measurements, indicating a possible subclinical effect.

Grass Straw Residues as a Feed Source for Wintering Beef Cattle

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Introduction

Oregon is one of the major producers of cool-season grass seed and is world renowned for producing seed which is high in purity, viability and volume. Since the 1960s, the Willamette Valley's production has accounted for 60 to 80 percent of the U.S. market supply of cool season grasses and, with Denmark, has dominated in supplying the international market with these grasses (Wilson and Conklin, 1981). Most grass seed produced in Oregon is grown in the Willamette Valley, a region 175 km long and 60 km at its widest point with an elevation of 65 m (Youngberg, 1980). This valley covers nine Oregon counties (Multnomah, Washington, Yamhill, Clackamas, Polk, Marion, Benton, Linn and Lane) which produce almost two-thirds of the total U. S. production of cool-season grasses (Conklin et al., 1989). This area produces a diversity of grass species, including fine fescue, tall fescue, hard or chewing fescues, perennial and annual ryegrasses, bentgrass, orchardgrass and bluegrass. Where these grasses are grown in the valley is largely dictated by soil characteristics.

After the seed crop is harvested, remaining straw residue is disposed of by open field burning. This practice came about in the late 1940's when it was discovered that field burning helped control *Gloeotinia temulenta* (blind seed) in perennial ryegrass (Hardison, 1976). According to Youngberg (1980), burning has been used for residue disposal, disease control, weed control and increased seed yields. Within the last two decades, field burning by grass seed producers has come under increasing public scrutiny. As a result, legislation has been passed in recent years to regulate how field burning is conducted and dictate the number of acres burned. The seed industry, in joint ventures with agricultural and other researchers, has been investigating other alternatives for residue disposal. One means of straw removal is to bale the residue. An export market for straw to Japan was developed in 1972 when Japan's dairy industry was looking for a low quality roughage source to feed in conjunction with their readily available high protein feeds such as soybean and fish wastes. Since it's development, the straw market in Japan has increased steadily over the past ten years in the amount of straw being exported, from 30,000 tons to 120,000 tons during the past two years (Conklin et al., 1989). In 1991, 250,000 tons of grass seed straws were exported to Japan (Ag. Fiber Association, personal communication).

In Eastern Oregon, cattle producers are at a competitive disadvantage relative to other regions of the U.S. in terms of cost-effective winter feeds. Traditionally, most producers depend on grass hays for winter feeding which are either purchased or grown on the producers' land from irrigated meadows. In times of drought, hay crops may be substantially reduced or nonexistent, causing market prices to drastically increase. As a result, producers are faced with the dilemma of either purchasing feed, reducing the size of their herds by increased culling, or both, in order to make it through the winter feeding period. The cattle industry's future in this region will depend, in part, on finding economical feed alternatives for the winter feeding period. The use of grass straw residues has been suggested, but a domestic feed market for grass straw has not developed because of concerns over the nutritional quality of straw and the presence of anti-quality factors (alkaloids) in straw which may hamper animal performance and health. Renewed interest in grass straw feeding for ruminant diets has occurred due to drought conditions and lack of feed in the intermountain region in 1988.

In the following thesis, a literature review focusing on the use of grass seed residues as a ruminant feed resource is presented (Chapter One). In Chapters Two and Three, research addressing current problems hindering the use of grass seed straw is reported.

The purpose of the research project is two-fold: (1) to evaluate the nutritional quality of grass straw residues produced in the Willamette Valley, and how quality is influenced by production and harvest techniques utilized by both the grass seed producers and straw baling contractors and (2) to evaluate the effect of endophyte-produced alkaloid concentration present in turf-type grass straw on the nutrition, physiology and performance of beef steers.

REVIEW OF LITERATURE

PART ONE: OREGON'S GRASS SEED INDUSTRY

Historical Overview of the Grass Seed Industry

The commercial grass seed industry began with grasses and legumes introduced in Oregon in 1920 (Middlemiss and Coppedge, 1970). Farmers found that the grasses thrived in the Willamette Valley climate. The cool, moist springs favored grass pollination and the warm, dry summers enhanced seed development, maturation and harvest with little danger of reduced seed viability (Conklin and Bradshaw, 1971; Conklin and Fisher, 1973). The grasses also tolerated the saturated soil conditions which occur during the months of November to April.

Soil type dictates which grass species is grown in a particular location. The soils in the Willamette Valley consist of soils varying from clay to clay loam classification (Youngberg, 1980). The Valley's northern end has soils consisting mainly of the Willamette, Chehalis and Woodburn soil series. These soils are well drained, show good response to fertilizer and are suitable for crop rotations which include cereal grains, grasses, orchards, forage crops, berries and hops. In the hilly regions of the north end, fine fescues and bentgrasses are grown mainly to help prevent soil erosion. Orchardgrass, bluegrass and tall fescue varieties are also grown in these northern regions. The soils in the southern end of the Valley are predominantly of the Amity and Dayton soil series. These soils have excellent topsoil, but they have a twelve inch impenetrateable layer of clay material located sixteen to twenty-four inches below the surface (Conklin and Bradshaw, 1971). In the Amity and Dayton soils, the ryegrass species, both perennial and annual, are mainly grown since they thrive on the winter flooding which occurs in these soils because of this clay layer. Turf type tall fescue varieties can also tolerate these soil conditions and are grown in these areas, with some bentgrass, orchardgrass and bluegrass grown in the better drained soils in the southern valley.

Grass seed is divided into three consumer use categories: lawn and turf use, cover crop and pasture use, and multi-purpose use (Wilson and Conklin, 1981). Lawn and turf use grasses are mainly fine fescues (chewings and red), bentgrass, and bluegrass. These grasses are easy to mow, can tolerate low cutting levels, have a rich green color, vigorous dense growth, and respond to irrigation and fertilization (Wilson and Conklin, 1981). Lawn and turf grasses are used mainly for lawns and golf course turfs in urban markets. Cover crop and pasture species are mainly orchardgrass and tall fescue. These varieties are combined with other grasses and legumes and used to seed pastures for grazing livestock, mainly in the Southeastern U.S. Annual and perennial ryegrasses are multi-purpose crops. Multi-purpose grass species are used in both lawn and cover crop seed mixtures and in winter overseeding of lawns in the Southeast since they have earlier germination and more rapid growth than other grass or legume species (Wilson and Conklin, 1981). A large export market also exists for Oregon seed: all bentgrass seed produced in the U.S. is exported, and an average of fifteen percent of the other cool-season grasses are shipped to overseas markets (Conklin et al., 1989).

The production of grass seed has experienced some major shifts within the last twenty years in Oregon. In the late 1960's and 1970's, annual ryegrass was the predominant species grown since it has a high seed yield, even though the price per pound was lower than that for perennial ryegrass (Middlemiss and Coppedge, 1970; Cook and Youngberg, 1981). This trend changed during the 1980's. During this time period, there was a dramatic increase in the amount of tall fescue and perennial ryegrass varieties grown in Oregon, with annual ryegrass production decreasing (Conklin et al., 1989). This production shift can be largely attributed to 1970 Federal Plant Variety Protection Act which stimulated plant breeding companies to develop proprietary varieties. Proprietary varieties are varieties developed by private firms who retain exclusive rights to produce and market the newly developed variety, and as such, these varieties are not available to the general public for propagation or release (Cook and Youngberg, 1981). These newer varieties are turf-type fescues and ryegrasses which have consistently higher seed yields of more than 200 to 300 pounds per acre over their traditional counterparts due to genetic improvements (Conklin et al., 1989). The number of proprietary varieties produced has increased rapidly because of a higher market demand and price paid to seed producers for these grasses. This has resulted in a decline in the prices paid for annual ryegrass, bluegrass and most forage types (CH_2M Hill and O.S.U., 1991).

Use of Open Field Burning as a Management Tool

According to Hardison (1976), the practice of open field burning started in 1948 when agronomists discovered that burning the crop residue after seed harvest would control blind seed disease in perennial ryegrass. Since that time, field burning has been adopted by grass seed producers as a means of field sanitation and crop residue removal. Other benefits from field burning include: control of ergot and other diseases; effective weed control; removal of old tillers to stimulate seed yield; insect control by destroying oviposition sites; improving genetic purity by destroying shattered seeds that remain postharvest in the fields; recycling nutrients such as potassium, magnesium, calcium, and phosphorus, and improving ease of crop establishment (Conklin et al., 1989). Burning is usually conducted soon after harvest and before regrowth occurs in the fall.

Early regulation of field burning consisted of regulatory boards issuing weather reports and daily burning advisories. During this time, producers were able to burn anytime, day or night. The practice of night burning was banned in 1966 when poor smoke dispersal conditions made the practice impractical. That same year, in mid August, Governor McCall issued a temporary field burning ban when heavy smoke impacted the cities of Eugene and Springfield. Regulation of field burning and smoke management by the Department of Environmental Quality (DEQ) did not begin until 1969 when over 5,000 field burning complaints occurred. By monitoring prevailing meteorological conditions, DEQ would designate the times, places and amounts of field burning allowed each day on an hourly basis to maximize the amount of fields burned under optimum smoke dispersal conditions with minimal impact on the general public (Dept. of Ag., 1990).

Public scrutiny over field burning continued to increase due to presence of smoke from burning fields in urban areas and Oregonians' views on having a clean and livable environment free from smoke or smog. The state legislature in 1971 passed a Senate bill which banned field burning by 1975. Also during that year, DEQ instituted a registration program for grass seed fields that were to be burned. Farmers had to accurately map out and pay a fee on a per-acre-basis in order to register particular field(s) for burning. This was done with the assistance of a permit agent. Department of Environmental Quality would give authorization to burn when the weather conditions were ideal for maximal smoke dispersion in a particular area or zone. The permit agent in that particular area or zone would notify registered growers to see if they were ready to burn their fields and to give the grower the authorization to burn. If the grower was not prepared to burn, he/she would have to wait until their particular zone had the authorization to burn again.

By 1975, more complaints were lodged against field burning and higher registration fees were charged to growers. In addition, the legislature that year passed a Senate bill that lifted the field burning ban and instituted an acreage "phase down" on the number of acres to be field burned in place of a total ban. By 1979, the legislature had limited the number of allowable acres for burning to 250,000 acres. During this time, some of the fee money collected for acre registration was being directed into research and development research activities, looking for workable alternatives for straw disposal besides field burning.

In the 1980's, the number of acres that were burned declined dramatically, but the public still complained. Some contributing factors to this decrease in burning were an increase in competition for burn permits, weather limitations hampering maximum smoke dispersal, and seed producers prioritizing which fields would be burned based on agronomic needs (seed production enhanced by thermal treatment), physical limitations (an area too steep for baling equipment to work on) or relative economic value of the seed crop (higher price paid for seed) and choosing to use other alternatives for straw disposal such as baling, propane treatment or other nonthermal methods of straw removal (CH_2M Hill and O.S.U., 1991). Another factor which also contributed to this decreased use of burning was the increase in the number of proprietary perennial tall fescue and ryegrass acreages grown which shortened the crop rotations. Historically, perennial ryegrass varieties were planted and the established field had a stand production of ten to twelve years. With these newer varieties, seed crops were being rotated after a five year period on average.

Public outcry over field burning didn't reach a fevered pitch until the summer of 1988. On August 3, 1988 an open field burn located four miles south of Albany, near the Interstate 5 Freeway, sparked a wildfire which generated smoke across the freeway. This resulted in a 23 car accident in which seven people died and 38 people were injured. The next day, a moratorium was imposed on open field burning and propane flaming pending a committee review of the public safety aspects of field burning. The task force investigating this incident determined that the proximity of the wildfire to the freeway was a significant contributing factor to the accident. As a result, eight days later, a fire safety buffer zone was required on fields located near Interstate 5 and other major highways in the Willamette Valley in which open burning was to take place. This zone "prohibited open field burning within the first quarter mile of the Interstate, but allowed burning in the second quarter mile if the first quarter mile was noncombustible and included 'wings' extending a half mile to the north and south of the field. Other designated highways required an eighth of a mile wide non-combustible area, extending a quarter of a mile in each direction from the field" in order for a field to be burned (St. of Or. DEQ, 1989). The public scrutiny over field burning continued to escalate due to the deaths from the August accident and changing attitudes on certain practices traditionally used in agriculture. This caused the legislative session in the following year to submit bills in the House and Senate to end field burning; however, both bills failed to be passed. In 1990, the DEQ contracted the Department of Agriculture to conduct the Smoke Management Program. Today, producers are continuing to decrease the amount of acreage that is field burned. The field burning regulation as it stands to date has further reduced the number of burnable acres from 250,000 to 140,000 acres. By the year 1998, only 40,000 acres will be allowed to burn by the current regulating system.

Current problem: Finding a Method of Residue Disposal

Annual straw production ranges from two to five tons per acre, depending on the grass species and variety, as well as the fertility of the soils on which the seed is grown, with higher fertility increasing the amount of straw produced (Conklin et al., 1989). The need for alternative means of straw disposal by the grass seed industry again has been brought to the forefront, demanding a method which will not impact the urban environment with smoke or particulate, but is economically feasible for the seed producers to incorporate into their production systems. Current alternatives to open field burning include: using the straw, propane flaming, bale or stack burning, and other nonthermal means of disposal such as flail chopping, crewcutting, reclipping and loafing, and soil incorporation of straw residue.

Methods of straw utilization

In terms of straw utilization, many uses for the residue have been investigated, with some being more successful than others. Potential uses of straw have been for livestock feed, mulch for mushrooms, blueberries, grapes and erosion control, fuels and fiber.

The major market for straw as a livestock feed is the export market to Japan as supplemental feed for their dairy industry. According to the Department of Agriculture (1990), an estimated 120,000 tons of straw were exported in 1990 and the export market is expected to grow at a rate of five percent per year. The Agricultural Fiber Association, composed of straw baling contractors, estimated that 250,000 tons of grass seed straws were exported to Japan in 1991. After the straw is baled, bales are compressed and loaded into shipping containers for ocean freighters bound for Japan. Also, in 1990, some 2,400 tons of bentgrass straw was shipped to Taiwan as cattle roughage (CH_2M Hill and O.S.U., 1991) which might open the export market to other Pacific Rim countries.

In terms of a domestic feed market, the domestic market for straw has not been well developed. Since 1988, renewed interest in feeding grass seed straw has occurred due to drought conditions in inland areas of the Pacific Northwest. The use of straw in a domestic market has not been realized due to the concern over nutritional quality, availability of other roughages and concern over the presence of endophyte-produced alkaloids. The possibility of a domestic market developing in the near future is very tangible and is directly related to further knowledge about endophyte's impact on animal performance and the nutritional quality of straws.

According to the Department of Agriculture (1990), an estimated 9,000 tons of straw residue are used in mulch/compost for growing mushrooms. It also makes a cheaper and less labor demanding mulch for blueberry plants as compared to sawdust. In a wine grape nursery, straw provided good moisture and weed control, showing some promise as a soil amendment (DEQ, 1989). It is estimated that 2,000 tons of straw mulch has been used for erosion control (Oregon Dept. of Ag., 1990) where it was found to increase soil infiltration and impede surface runoff on steep banks and hillsides. Straw mulch was used as an erosion control by the BLM, Forest Service and Highway Department between 1973 and 1977 and in Christmas tree farms in 1984 through 1986 (Conklin et al., 1989). Although the amount of straw residues used in these functions is relatively small, the use of residues could expand in the near future if field burning is totally abolished.

Extensive research into the use of straw as a fuel has occurred from 1969 to 1986. The use of straw in boiler fuels in the forms of straight bales, chopped straw, and cubes has been investigated (CH_2M Hill and O.S.U., 1991). Conklin and co-workers (1989) reported burner trials were carried out by major hog fuel consumers including Weyerhauser, Georgia Pacific, Eugene Water and Electric Board, University of Oregon, Bohemia, Willamette Industries, Energex, Coen, Turco Industrial Combustion and others. One major problem in burning straw is the formation of a glassy slag at temperatures of 1,500^{o}F, which is below temperatures for wood fuel combustion (1,800 to 2,000^{o}F). Slag is formed by the melting of potassium, sodium and other minerals which are concentrated in grass seed straws. Slag deposits clog up boiler grates and deposit in fluid beds, thus requiring removal since they cause mechanical trouble for the upper furnace and heat exchange surfaces (Conklin et al., 1991) in boilers. In addition, straw requires some special equipment for handling and pollution control, making it more expensive to use than hogged wood fuel (Conklin et al., 1989). The use of straw as fireplace logs or for pellets used in pellet stoves is possible, but is highly dependent on the development of a market where consumers are receptive to these products as well as incorporating some other fiber constituents (wood chips) to alleviate the slag formation problem.

The use of straw in fiber products such as paper, particleboard, corrugating medium, newsprint, and fiberboard has also been investigated. Corrugating medium appeared to offer the best potential use for straw residues according to Conklin and co-workers (1989) because of equipment costs required in handling and pulping the straw for particleboard. At best, straw residues could be used only as an extender or supplement to the existing wood fibers used in particleboard production due to plant modification issues and low overall volume when utilizing straw (Conklin et al., 1991). Also, an increase of more than ten to twenty percent straw used in the fiber mix would require public acceptance and structural standards to be met in order for straw to be used.

Thermal means of straw removal

Propane flaming is recognized by the Department of Environmental Quality and the Oregon Department of Agriculture as an approved alternative to open field burning and usage of this tool has increased within the last decade. According to the Oregon Department of Agriculture (1990), 40,000 to 60,000 acres are burned by propane annually. The general requirements for propane burning are: loose straw must be removed, the stubble must be cut and the remaining field biomass must not be able to sustain an open fire. A farmer is allowed to propane burn as many acres, on any day, on any location as long as it is not prohibited by adverse weather conditions or air quality. Acres that are propane burned are exempt from all fees and registration requirements that open burning acres require. Growers in both the Southern and Northern valley use propane flaming as a means of field sanitation on perennial ryegrass and tall fescue fields after straw baling. Costs for propane burning and other methods of straw removal vary depending on field size, specific equipment used as well as other factors (Mellbye, 1990). In a survey by Cross and Mason (1989) analyzing the costs for field sanitation in the Willamette Valley, propane flaming averaged $37.79 per acre (range $33.85 to $41.74). If the producer could sell or trade his straw for baling services, they found the average cost to propane was $29.98 per acre (range: $25.73-34.24), but if the producer did not sell or trade the straw, the cost per acre averaged $50.80 (range: $44.56 to $57.04)--an increase in cost of $20.82 per acre. This difference in cost for growers with no market for their straw was attributed to the costs of removal (Cross and Mason, 1989).

As a result of increased competition for field burning permits, seed producers who lack a market for their straw will resort to stack burning. The residue is baled and roadsided, to be ignited at a later date. According to the Department of Environmental Quality (1989), there was an increase in this practice as a result of the export market and the additional buffer zones required in field burning since the I-5 accident. No statistics are available on the amount of stack burning conducted, but the practice is expected to continue, especially as the number of acres allowable to burn is further decreased. In terms of regulations, this practice is regulated by atmospheric conditions conducive to open burning. State agencies are monitoring this process for potential smoke problems.

Nonthermal Means of Disposal: Mechanical Methods

Current methods of mechanical removal include flail chopping (with or without thatching), crewcutting, reclipping and loafing and soil incorporation of straw residues. All of these methods of disposal require a companion herbicide treatment to control volunteer grass seed germination after fall precipitation and in some instances, fields need to be chemically treated again in the spring for weeds that germinate during the winter (Conklin et al., 1989; Cross and Mason, 1989; CH_2M Hill and O.S.U., 1991). Because of this increased requirement for herbicide treatment with these mechanical methods, the cost of utilizing these methods has increased.

Flail chopping is done after the majority of straw is removed from the field; it involves clipping of the stubble close to the ground and decreasing the size of remaining residue left on the ground. This is done to stimulate seed yield as well as increase the effectiveness of herbicide application (CH_2M Hill and O.S.U., 1991). Thatching is sometimes done in conjunction with flail chopping to remove old crown growth from around the plant.

Crewcutting is another method that requires straw to be removed before application. This process removes residue from the field by clipping standing plant material at ground level and sweeping and collecting the chaff from the surface (Oregon Dept. Ag., 1990). One drawback to this method is the process stirs up a lot of dust and some of this dust gets incorporated into the straw loaf, thus the loaves formed after crewcutting cannot be burned and are usually left in the field to decompose. Research has shown this method approximates the physiological response of burning by eliminating older, non-reproductive tillers, allowing for new tiller development at the soil surface, particularly in perennial ryegrasses, tall fescues and orchardgrass (Conklin et al., 1989). According to Mellbye (1990), crewcutting removes more residue and weed control is usually better as compared to flail chopping.

Reclipping and loafing utilizes a self-propelled swather to windrow the remaining stubble and residue and is followed by a loaf stacker to roadside the residue (CH_2M Hill and O.S.U., 1991). Usually, these loaves are burned at a later date when weather conditions permit.

And finally, soil incorporation of straw residues is done on annual ryegrass fields in the southern valley. This practice is used more often in place of open field burning on these fields. After harvest, the straw is flailed or sometimes baled and the remaining stubble is then plowed under. A few drawbacks to this method are an increase in production cost, increased cost for weed control since weed seeds in the residue are incorporated into the soil, and an increase in lower product quality in the marketplace (Conklin et al., 1989).

PART TWO: OREGON'S BEEF CATTLE INDUSTRY

Feeding Management in the Winter

Feeding costs represent between 50 and 75% of the total expenses related to cow/calf beef cattle production (Anderson, 1977). Cattle producers in the Pacific Northwest are at a competitive disadvantage in terms of winter feeding costs. During the winter, most cattle producers must find an alternate forage base to feed their cattle herds since the ranges grazed during the summer months have gone dormant and lack large amounts of feed to sustain cattle. Due to their location and the shipping costs involved, cattlemen utilize hay as a winter feedstuff rather than other feeds, particularly concentrates, since hay is more readily available and cheaper to acquire. Hay must be either grown on the rancher's own land or purchased from a local market which contributes greatly to production costs. Costs for alfalfa hays have ranged from $85 to over $100/ton and other hays have ranged from $65 to $85/ton over the last five years (Oregon Agri. Stats. 1991). If a producer grows his own hay from irrigated meadows, these meadows cannot be used as grazing pasture. This aspect may put a further constraint on cattle producers if they are denied access to public lands for grazing in the near future and must resort to using their own meadows as grazing lands for their cattle. The future of this industry in this region will be highly dependent upon finding alternative feed sources during the winter months.

Use of Grass Seed Straws as a Winter Feedstuff

The use of grass seed straw residues has been suggested as a possible winter feedstuff, but the utilization of these residues has not been realized primarily for two reasons: (1) perception of grass seed residues as "straw" in terms of nutritional quality, and (2) the concern over the presence of endophytes in these residues and the alkaloids these fungi produce and how they impact animal performance.

The general perception that grass seed straws are on the same nutritional plane as cereal grain straws has existed for the past twenty years or more. In actuality, grass straws are more similar to low quality meadow or grass hays in terms of crude protein and fiber content (Table 1). Cereal grain straws are extremely low in protein, ranging from two to four percent crude protein on a dry matter basis. In contrast, grass seed straws range from four to seven percent, with some straws containing levels as high as eight percent. This is comparable to low quality meadow hays which have protein levels ranging in the five to eight percent range (Table 1). Worrell and co-workers (1986) reported crude protein levels as low as 4.9 percent in meadow hay that was harvested in the month of August. Most meadow hay is harvested during the months of July and August during late stages of maturity. Many producers would harvest earlier if they could get their equipment on the meadows. These meadows are usually flooded by elevated water tables from melted snow pack and are still soggy in June. In addition, producers delay meadow hay harvest to ensure they can complete their harvest without rain, since this can lower the nutritional quality of the hay by causing moldy hay and nutrient leaching. And finally, producers delay harvest to maximize the amount of hay produced. Plants in late maturity are highly lignified and have significantly lower levels of crude protein. In terms of neutral detergent fiber components, an indigestible plant cell wall fraction containing hemicellulose, cellulose, lignin, silica and heat-damaged proteins, grass seed straws are more similar to low quality meadow hays rather than cereal grain straws. Generally low quality meadow hays and grass seed straws have NDF levels (on a percent basis) in the upper 60's to mid 70's range, while cereal grain straws have levels in the upper 70's to 80's. The NDF content is more often considered as an indicator of intake potential among or within forage species (Fahey and Berger, 1988). According to Van Soest (1982), plant cell wall components are the primary restrictive determinant of intake, thus cereal grains will have lower intakes due to higher NDF as compared to grass seed straws and meadow hays.

Endophyte and Alkaloids in Tall Fescue and Perennial Ryegrass

Concern over endophytes has also hampered grass straw feeding. The endophyte is a fungus that spends it's life cycle within the plant tissues. The fungi that infect tall fescue and perennial ryegrass plants, *Acremonium coenophialum* and *Acremonium lolii*, have similar characteristics: both fungi are transmitted by seeds and give no outward sign of infection on the plants (Hinton and Bacon, 1985; Siegel et al., 1987; Bacon and Siegal, 1988; Bacon and DeBattista, 1991). Because of this, these fungi are classified as Deuteromycetes (Fungi Imperfecti) and since the host plant flowers normally, these plants are indistinguishable from nonhosts in mixed populations (Clay, 1991).

The fungal distribution in a tall fescue or perennial ryegrass plant changes over the length of the growing season. The active mycelium (vegetative part of the fungus) present in the seed are closely associated with the aleurone layer; during germination, the fungus invades the starchy endosperm (Siegal et al, 1985). Within two to three weeks after sheath differentiation in the first leaf occurs, the mycelium infects the grass seedling (Bacon et al., 1986; Bacon and DeBattista, 1991). During the vegetative and dormant periods of the grass growing season, the fungus is located in meristematic tissue of the shoot apex (Bacon, 1983). The fungus does not penetrate living cells, but resides in the intercellular spaces (Bacon, 1983; Bacon and Siegel, 1988). In time, the mycelium will infect the stem and other leaf tissue (Bacon et al., 1986). As the plant reaches maturity and inflorescence develops, the fungus enters the ovule and eventually migrates into the newly-formed seed (Bacon and Siegel, 1988). In their study on the distribution and ultrastructure of the tall fescue endophyte, Hinton and Bacon (1985) reported no fungus in the leaf blade, but it was distributed throughout the leaf sheath. Siegel and co-workers (1984) also reported similar findings that leaf sheaths and seeds contained the highest concentration of endophyte, followed by the crown and stem, with leaf blades and roots having a small concentration of endophyte. A study by Lyons et al. (1986) showed that the occurrence of ergopeptides was spread throughout the entire plant. They reported the occurrence of ergopeptide alkaloids in leaf blades, sheaths, inflorescences and stems, with the highest concentration in leaf sheaths and blades. In addition, they also found that ergovaline constituted 84 to 97 percent of the total ergopeptide concentration.

The endophyte produces various types of alkaloids. The major alkaloid types produced by the endophyte include perloline, the loline alkaloids (mainly n-acetyl loline and n-formyl loline), peramine alkaloids, ergopeptide (amino acid) alkaloids (mainly ergovaline) and in perennial ryegrass, lolitrems (Yates, 1983; Bacon and DeBattista, 1991; Dahlman et al., 1991). In terms of chemical constituents, the perloline alkaloid contains a dizaphenanthrene nucleus; loline alkaloids contain a pyrrolizidine nucleus; peramine alkaloids are composed of a $C_{12}H_{17}N_5O$ basic indole derivative; the ergopeptide alkaloids are lysergic acid amide derivatives and lolitrems are complex isoprenoid-substituted indole metabolites (Rall and Schleifer, 1980; Yates, 1983; Dahlman et al., 1991; Bacon and DeBattista, 1991).

The grass and endophyte form a mutualistic symbiotic relationship in which both organisms benefit. The host plant provides nutrients, protection, reproduction and dissemination means for the fungus (Bacon and Siegel, 1988). In turn, the fungus improves plant growth, seedling vigor and germination rates, thereby improving the overall survival of the infected grass (Pedersen et al., 1990). Hill and co-workers (1990) reported that endophyte infection increased dry matter production per tiller and greater leaf areas than in noninfected plants. In mixtures with non-infected plants, tall fescue plants that are endophyte-infected were larger and generally more competitive (Hill et al., 1991). Marks and co-workers (1991) found that the presence of endophyte in tall fescue enhances competitive ability, even at low densities, but in the case of perennial ryegrass, endophyte infection may be advantageous only under particular or extreme circumstances. In addition to this, the alkaloids are a deterrence and/or provide tolerance to herbivory by both insects and grazing animals and increase the infected plants resistance to diseases and pests (Clay, 1991; Bacon and DeBattista, 1991; Dahlman et al., 1991; Siegel et al., 1987).

The amount of alkaloids present in an infected plant is dependent upon time of season, amount of fertilization, moisture, stage of maturity and variety (Yates, 1983). Perloline decreases as a plant matures. The concentration of perloline in mature shoots was approximately 73% of that found in young succulent plants; in vegetative regrowth, the highest concentration is found in the roots since this alkaloid is synthesized there (Gentry et al., 1969). Perloline level in tall fescue forage has been shown to increase during the months of July and early August and with increased nitrogen fertilization (Gentry et al., 1969; Hemken et al., 1984). Belesky et al. (1987)

found that the ratio of loline derivative alkaloids increased under high nitrogen in the fall of two study years and concluded that the production of these alkaloids may be more closely associated with short-term weather conditions rather than endophyte infection frequency. In a later study conducted by Beleskey and co-workers (1988), they found an increase in both ergopeptide and loline alkaloids in leaf blade tissue during conditions of water stress which was attributed to an increase in alkaloid synthesis rather than a decrease in phytomass. In conditions of severe water stress, 75% of plants with no endophyte died while all the plants containing endophyte survived (Arachevaleta et al., 1989). In a later study, Arachevaleta et al. (1992) found that ergopeptide biosynthesis was increased by high rates of nitrogen fertilization and moderate water deficit. Ellis and co-workers (1988) reported that nitrogen fertilization significantly increased ergovaline levels in leaves and stems and approached a significant level in seed heads. They also reported ergovaline concentrations in plant tissues reached peak levels on different dates: stems were highest in mid May, leaves during late May and seed heads were highest during late June (Ellis et al., 1988).

Alkaloids Impacts on Animal Production

These alkaloids have varying effects on herbivores, especially grazing animals. The focus of this discussion will be on those alkaloids which have been reported to have an impact on animal production. In terms of an economic impact by fungal endophytes, Hoveland (1993) has conservatively estimated beef cattle annual losses to total $609 million, with $354 million in reduced calf numbers and $255 million in reduced weaning weights. Alkaloids in tall fescue have caused fescue foot, summer syndrome or fescue toxicosis, fat necrosis, agalactia and reproductive problems (Hemken and Bush, 1989; Hemken et al., 1984; Stuedemann and Hoveland, 1988).

Symptoms of summer syndrome or fescue toxicosis include reduced growth, reduced milk production, decreased feed intake, rough hair coat, elevated body temperature, increased respiration rate, lower serum prolactin levels, excessive salivation, and reduced reproductive performance (Hemken et al., 1984). This condition usually occurs during the summer months when the environmental temperatures are high (greater than 23^{o} C). This was illustrated in a study by Hemken et al. (1981) in which Holstein calves consuming GI-306 (low toxic) and GI-307 (high toxic) tall fescues had essentially no difference in intake, weight gain, rectal temperature and respiration rates at lower ambient temperatures (16 to18^{o}C). They concluded that both environmental temperature and the presence of the toxic substance are necessary to produce the summer toxicosis syndrome. Crawford and co-workers (1989) calculated that there was an approximate 68 g/d depression in ADG for each 10% unit increase in endophyte infection occurrence during the spring and summer grazing of stands made up primarily of tall fescue.

No agreement has been reached yet as to which of the tall fescue alkaloids cause these animal disorders. For a time, perloline was thought to be the causitive agent of tall fescue toxicosis since Bush and co-workers (1970) showed that perloline inhibits in vitro cellulose digestion by rumen microbes. This work was supported by a later study performed by Bowling and co-workers (1975) in which perloline reduced cellulose digestion, as well as lowered crude protein digestibility, decreased the production of rumen volatile fatty acids and caused a slight increase in temperature for a two day period in sheep.

However, the role of perloline in summer syndrome was shown to not be a factor. Hemken and co-workers (1979), in a study evaluating a high (GI-306) and low perloline (GI-307) content tall fescue varieties, found that the low perloline tall fescue caused summer toxicosis symptoms: average feed intake was 5.5 (low perloline) vs 8.7 kg/d (high perloline) and milk production was 10.8 (low perloline) vs 17.3 kg/d (high perloline) for a two year time period. Similiar reduced gains were reported by Steen et al. (1979) for yearling steers consuming the same low and high perloline tall fescue varieties. In addition, these steers consuming the low perloline fescue variety had higher respiration rates, long- rough-dull haircoats, increased heart rates, excessive salivation and spent most of the day in the shade (Steen et al., 1979; Bond et al., 1984). These studies indicated that in selecting fescue with a low perloline content, other anti-quality factor(s) were increased which resulted in the precipitation of summer syndrome.

Ergopeptides, such as ergovaline, have also been implicated as the causitive agent of summer syndrome. Osborn and co-workers (1992) reported reduced feed intakes, heart rates, and infra-red temperatures for the ear canal, pastern and coronary band and increased rectal temperatures and respiration rates for Holstein steers consuming either a fungus-infected seed and hay and a fungus-free seed and hay diet mixed with ergotamine tartrate as compared to fungus-free seed and hay diets. Hannah et al. (1990) discovered that an ergovaline content of 3 ppm reduced ruminal and total tract OM, NDF and cellulose digestibilities, decreased ruminal fluid dilution and outflow rates as well as increased rectal temperatures. Peters et al. (1992), investigating the effect of grazing an endophyte-free and an endophyte-infected tall fescue pastures on cow performance, found that the milk production for the cows on endophyte-infected fescue were 25% lower than that by cows on the noninfected fescue. Calves weaned by cows on the endophyte-infected fescue were lighter than the calves weaned by cows grazing the noninfected fescue. They concluded that the decreased performance was not explained by reductions in feed intake, but rather, altered nutrient utilization. Beleskey and co-workers (1988) also reported decreased ADG with increasing ergovaline content in tall fescue during the spring and summer of a two year study, but when the entire grazing season was considered (April to December), they found no significant association between the alkaloid and ADG due to variation in ergopeptide alkaloid content in the pastures. They suggested that ergopeptide alkaloids function in an insidious or latent manner in the grazing animal, requiring additional environemental or nutritional stresses operating upon the plant or animal or both, in order to elicit clinical symptoms of the fescue toxicosis syndrome.

Endophyte infection has also been shown to reduce serum prolaction levels during fescue toxicosis. Hurley et al. (1980) reported calves that were fed GI-307 tall fescue had lower basal prolactin than those calves fed GI-306 tall fescue (1.8 vs 6.0 ng/ml). Lipham et al. (1989) also found similar results; steers that grazed endophyte-infected fescue pasture had decreased basal serum PRL concentrations (< 1.0 ng/ml) as compared to those grazing a low endophyte pasture (5.3 ng/ml).

Fescue foot is another malady caused by the ingestion of tall fescue. This toxicosis results in gangrene of the animal extremeties, particularly tails, hooves, and ears and occurs during cold temperatures, particularly in the late fall and winter. According to Hemken and Bush (1989), fescue foot starts out with a reduction in weight gains or weight loss. Animals have a rough hair coat, arched back, soreness in one or both rear limbs (Hemken et al., 1984). Hyperemia of the coronary band occurs, with some swelling; if the animals continue eating the infected fescue, eventually the hooves may be sloughed off (Hemken and Bush, 1989). Read and Camp (1986) reported that five tester animals in a Kenhy fescue grazing trial had fescue foot; three of the animals grazing the high endophyte level had lost their tail switches, another had developed necrosis of the coronary band on the right hoof and necrosis at the tail tip, and another animal had developed a necrotic tail tip that was eventually sloughed off. In a study evaluating five varieties of tall fescue for their fescue foot potential, Cornell et al. (1982) found that winter grazing of KY-31 was most toxic in producing signs of fescue foot with Kenhy, Mo-96 and Kenmont being intermediate in toxicity as measured by visual observations of knuckling, lameness, swelling about the dewclaws and tail tip or coronary band necrosis. Carr and Johnson (1969) were the first to hypothesize that the toxic principle in tall fescue does cause considerable vasoconstriction of the extremeties during some point in the toxicosis syndrome. They theorized that the toxic entity leads to both an increase in rectal temperature and respiration rate at high environmental temperatures as well as reduced skin temperatures of the distal portion of the tail at low environmental temperatures. Walls and Jacobson (1970) found that environmental temperature had considerable influence on the skin temperatures of the tail when feeding fescue hay. They associated this decrease in tail skin temperatures with decreases in blood flow through the tail.

Fat necrosis is characterized by hard fat masses located primarily in the adipose tissue of the abdominal cavity (Stuedemann et al., 1975). According to Hemken et al (1984), other symptoms include elevated body temperature, rough hair coat, lameness, and the seeking of shade or water by cattle. This condition is accentuated by the application of high levels of nitrogen or poultry litter. Stuedemann and co-workers reported fat necrosis occurred in 60% of the cows grazing a high nitrogen fertilized fescue pasture (703 kg broiler litter). In addition to fat necrosis, plasma cholesterol concentrations were the lowest (114 mg/dl vs 134 and 127 mg/dl) for these cows on high nitrogen pastures. Lipid metabolism is altered in cattle grazing tall fescue, but exactly how this change comes about is unknown. Ito et al. (1968) postulated this change in fat composition was due to the compaction of fat cells which results in a circulatory disturbance. As a result, either certain circulating enzymes or an imbalance in the dynamics of fat deposition triggers the formation of lesions. Another possible explanation for the lesion formation is the vasoconstrictive properties of tall fescue. Rumsey et al (1979) theorized that the vasoconstriction may lead to a general febrile, or feverish, condition of the body, including the depots of fat, thus resulting in lesions forming in the peritoneal fat depots, since these depots are more susceptible to lesion formation than other fat depots.

Reproductive problems have also been associated with feeding of tall fescue forages. Bond and co-workers (1981) reported that the conception time for ewes grazing GI-307 or KY-31 infected fescue or orchardgrass pastures was significantly longer for ewes grazing infected fescue than those ewes grazing orchard grass (75 d GI-307; 64 d KY-31 vs 27 d Orchardgrass). In another study investigating the effect of ewes grazing infected fescue pastures (GI-307 and KY 31) or orchardgrass pastures on ovum fertilization failure and embryonic mortality, the proportion of ewes returning to estrus was significantly higher for ewes grazing the GI-307 fescue than the orchardgrass pastures (Bond et al., 1982). These results indicate that the lower fertility exhibited in these ewes was attributed to embyonic mortality rather than fertilizaiton failure.

Reproductive failures have also been reported in beef cattle. In a recent survey, Hoveland (1993) reported that a 90% or higher calving rate is attainable on endophyte-free tall fescue pastures with good management, but the average calving percentage of cows maintained on endophyte-infected tall fescue was estimated to be only 74% due to reduced conception rates. Boling (1985) reported calving rates for cows grazing a low endophyte-infected fescue were 86% compared to 67% for cows grazing high-endophyte infected fescue. Reproduction in cattle may be further compromised by retention of the winter coat as well as increased susceptibility to high environmental temperatures (Porter and Thompson, 1992).

Fungal endophytes severely affect horses. Garrett and co-workers (1980) conducted a survey analyzing the incidence of reproductive problems in mares. They found that the major problems of mares consuming tall fescue forages included agalactia (53%), prolonged gestation (38%), abortion (18%) and thick placentas (9%). In addition, foal losses due to consumption of fescue were three times greater and the incidence of agalactia twelve times greater with tall fescue than other forages. Putnam et al. (1991) also found similar effects on pregnant mares grazing endophyte-free and endophyte-infected KY-31 tall fescue. Of the mares grazing endophyte-infected fescue, 91% of the mares had obvious dystocia, with only one foal surviving the natal period. They also reported a 20 d increase in mean duration of gestation as well as no evidence of udder development or lactation period in mares grazing the infected fescue. Endophyte effects on reproduction in horses is more severe than in ruminants.

The exact mechanism of action by alkaloids is not fully elucidated; different modes of action as well as synergistic reactions between the ergot alkaloids and n-acetyl-loline alkaloid have been proposed. Ergot peptides have vasoconstrictive effects (Berde and Schild, 1978). Porter and Thompson (1992) propose that reduced blood flow to internal organs caused by possible additive effects of ergovaline and n-acetyl-loline alkaloids could compromise reproduction through hypoxia. In addition to their vasoconstrictive, dopaminergic, and antiserotonergic effects, ergot alkaloids can inhibit implantation, stimulate contraction of the gravid uterus, resulting in spontaneous abortions, as well as have embryotoxic effects (Berde and Schild, 1978; Rall and Schleifer, 1980). Reductions or decreases in lactation may be attributed to either the ergot peptide alkaloid's inhibitory effects on PRL secretion before parturition or reduced feed intake (Porter and Thompson, 1992).

Relationship Between the Cattle and Grass Seed Industries

Both the beef cattle industry and grass seed industry have some management problems, with regard to winter feeding and grass seed straw disposal. One possible means of overcoming these problems would be the development of a domestic market for grass straw in the Pacific Northwest. Some major conflicts first have to resolved, however, before this can occur, such as nutritional quality and endophyte's effects, as previously discussed. In addition to this, other alternative forages, particularly alfalfa hay, have to be economically nonfeasible for use. What now follows is a discussion of research to address these conflicts conducted during the summer of 1991 and winter of 1991-92 in which the nutritional quality of grass straws and the endophyte's effect on animals were evaluated .

Table 1. Nutritional Comparisons of Low Quality Meadow Hays, Grass Seed Straws and Cereal Grain Straws[a]

Reference by Forage Type		Nutritional Quality Percent Dry Matter Basis		
A. Low Quality Meadow Hay	**Description**	**CP**	**NDF**	**ADF**
Hunt et al., 1989	Meadow Fescue	6.6	65.4	39.0
Sanson and Clanton, 1989	Warm- and Cool-Season Grasses	5.2	70.8	46.1
		7.0	74.4	45.6
Sanson et al., 1990	Warm- and Cool-Season Grasses	4.3	72.9	46.2
Waggoner et al., 1979	Native Meadow and mixtures of Brome, Fescue and Chrested Wheat Grasses	8.2	66.3	42.1
Worrell et al., 1986	Mixture of Warm- and Cool-Season Grasses	8.5	68.1	34.3
		6.0	71.9	37.6
		4.9	70.8	38.7
B. Grass Seed Straws				
Church and Champe, 1980	Annual Ryegrass	3.4	------	44.9
Guggolz et al., 1971	Fescue	5.1	-----	53.0
Ralton and Anderson, 1970	Perennial Ryegrass	5.5	-----	50.6
	Bluegrass	8.9	-----	43.7
	Bentgrass	4.6	-----	45.6
	Annual Ryegrass	4.8	------	49.7
Kellums et al., 1984	Perennial Ryegrass	6.9	71.7	42.5
Kellums, 1985	Perennial Ryegrass	4.23	68.8	44.0
Phillips et al., 1975	Bluegrass	5.5	------	-----
	Red Fescue	3.7	-----	------
Phillips and Vavra, 1979	Perennial Ryegrass	8.9	-----	43.2

[a] General overview to allow for comparison of three forage types and is not all inclusive.

Table 1. Nutritional Comparisons Of Low Quality Meadow Hays, Grass Seed Straws and Cereal Grain Straws (continued)[a]

Reference by Forage Types		Nutritional Quality Percent Dry Matter Basis		
B. Grass Seed Straws (continued)	**Description**	**CP**	**NDF**	**ADF**
Youngberg and Vough, 1977	Bluegrass	7.7	73.2	43.6
	Perennial Ryegrass-Turf type	6.7	68.1	42.4
	Tall Fescue	5.7	69.3	42.5
	Bentgrass	5.2	67.7	41.1
	Perennial Ryegrass-Forage type	4.9	72.1	45.5
	Orchardgrass	4.8	79.0	49.6
	Annual Ryegrass	3.7	75.6	50.5
	Chewings and Red Fescue	3.1	81.1	51.5
C. Cereal Grain Sraws				
Church and Santos, 1981	Wheat	3.8	-----	49.0
		2.6	-----	53.1
Herrera-Saldana et al., 1982	Wheat	2.9	-----	50.1
Horton, 1978	Wheat	2.3	-----	-----
	Barley	3.85	-----	-----
	Oat	2.2	-----	-----
Horton and Steacy, 1979	Barley	3.9	------	-----
	Wheat	2.5	-----	-----
	Oat	2.6	-----	-----
Kernan et al., 1979	Wheat	3.6	-----	-----
	Oat	3.8	-----	-----
	Barley	4.9	-----	-----
Males et al., 1982	Wheat	3.4	82.6	56.7
Pritchard and Males, 1982	Wheat	2.5	78.5	55.1

[a] General overview to allow comparison of the three forage types and is not all inclusive.

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NUTRITIONAL QUALITY OF GRASS SEED RESIDUES HARVESTED FOR LIVESTOCK FEED IN WESTERN OREGON

Introduction

In 1990, greater than 1,000,000 metric tons of grass seed straw was produced in the Willamette Valley (CH_2 M Hill and O.S.U., 1991). The traditional method of straw disposal has been open field burning. However, within the past twenty years, open field burning has come under increasing public scrutiny due to smoke encroachment on urban areas and the I-5 Freeway traffic accident in August, 1988 in which 38 people were injured and seven people lost their lives. Within the last ten years, grass seed producers have turned to other alternative methods of straw disposal; one such method utilized is baling the residue for livestock feed. The primary market for straw is the export market to Japan. A domestic feed market for straw has not been fully developed, but renewed interest in the winter feeding of grass seed straws has arisen due to drought conditions in the inland areas of the Pacific Northwest.

Very little is known about the nutritional quality, in terms of grass species or varieties within species, of Willamette Valley grass seed straws. With the recent renewed interest by cattle producers in feeding grass seed straws, questions over straw's nutritional quality have arisen. A study was conducted in 1975 by Youngberg and Vough (1977) in which eight species of grass straw were sampled. However, this survey had a small number of total samples (less than 100) and samples were collected from loose straw fields a few days after combining, not at the time of straw baling. Information concerning harvesting factors, such as swathing dates, days from swathing until straw baling or if the straw was rained on before baling which have an influence on nutritional quality, were not evaluated in this survey. Since this study, there has been a rapid shift in the grass seed industry to produce turf-type grasses rather than forage-types, resulting in the introduction of the endophyte in new tall fescue and perennial ryegrass varieties. Cattle producers have also voiced concerns over the presence of endophyte in straw and whether or not an endophyte-produced alkaloid present in straw would have a negative impact on animal performance and health. No data currently exists on alkaloid content in straw species and varieties within species. Therefore, a survey was conducted during the summer of 1991 to evaluate the nutritional quality of Willamette Valley grass seed straws and alkaloid (ergovaline) content.

Materials and Methods

In mid April of 1991, the Agricultural Fiber Association, an organization composed of baling contractors and grass seed growers, was consulted to obtain a group of baling cooperators who would be willing to participate in the summer sampling of grass seed straws. The twelve baling contractors who agreed to participate were based in both the north and south ends of the Willamette Valley. Each day between 0600 to 0700 h, during the months of July to mid September, these baling contractors were contacted by telephone to receive daily field baling locations which encompassed a seven county area (Clackamas, Benton, Polk, Linn, Lane, Marion and Yamhill counties). Grass species sampled included tall fescue (*Festuca arundinacea* Shreb.), orchardgrass (*Dactylis glomerata* L.), perennial ryegrass (*Lolium perenne* L.), annual ryegrass (*Lolium multiforum*) and bentgrass (*Agrostis* L.). Perennial ryegrass composed 46.3% of the total samples (136 samples), followed by tall fescue at 41.5% (122 samples), bentgrass at 8.8% (26 samples) and all other grasses at 3.4% (Figure 1). Straw bales were sampled with a forage sampler, powered by a portable gas generator. Bales were sampled randomly from either stacks or individual bales throughout the field; enough straw was removed to provide 150 g of sample when ground through a 1 mm Wiley Mill screen (10 to 20 cores per sample). Samples were given identification numbers, identifying the sample by grass species and variety, seed producer, baling contractor, and field location. After the completion of the grass seed harvest, letters and questionnaires were sent to seed producers (Appendix) to obtain background information on the seed field. Follow-up phone calls were conducted to unresponsive seed producers in January 1992 to obtain unknown species varieties. Precipitation information was obtained from the Climatological Data pamphlets published by the National Oceanic and Atmospheric Administration (NOAA).

Laboratory Analysis and Calculations. Straw samples were ground to pass a 1 mm Wiley mill screen. Ground samples were analyzed for DM and Kjeldahl N (AOAC, 1984), ADF and NDF (Goering and Van Soest, 1970). Acid detergent insoluble N (ADIN) was calculated by Kjeldahl N on the ADF residue (Goering and Van Soest, 1970). In vitro digestibility was determined using the Tilley and Terry (1963) procedure. Dr. George Rottinghaus at the University of Missouri used high pressure liquid chromatography (HPLC) analysis to measure ergovaline content in tall fescue and perennial ryegrass samples. Data tables are designed to indicate the nutritional quality of the grasses in decreasing order for each nutritional analysis.

Statistical Analysis. Species means were separated by Least Significant Difference (LSD) using a critical T test ($P<.10$) for CP, ADIN, ADF, NDF and IVDMD (SAS, 1987). Harvest factor means, harvest date, length from swathing until baling and precipitation, were also separated by LSD using a critical t test ($P<.10$).

Results and Discussion

Background Information. Orchardgrass and annual ryegrass had the earliest harvest dates for the species sampled, followed by tall fescue, perennial ryegrass and bentgrass (Table 2) during the 1991 baling season. Annual ryegrass had the shortest time length from swathing to baling, followed by orchardgrass, bentgrass, tall fescue and perennial ryegrass. In terms of precipitation, bentgrass had the highest levels due to rainfall occurring in late August and early September, during the time this grass species was harvested. Annual ryegrass had the lowest amount of precipitation, followed by orchardgrass, perennial ryegrass and tall fescue.

This information was gathered to assist prospective cattle producers who would consider buying straw as a winter livestock feed. These variables can be used as general guidelines in purchasing straw. Knowledge about precipitation is very important, since it can have a large impact on the nutritional quality of straw. Although late precipitation occurred during bentgrass baling in 1991, the amount was relatively small and had little effect on nutritional quality of this straw. Knowledge about when certain grass species reach maturity and how long until they are baled can help a producer in planning when to buy a specific species of straw, as well as make transportation and storage arrangements ahead of the time of purchase.

Crude Protein. In ruminants, the dietary need for protein is a combination of needs to nourish the microorganisms and for an adequate supply of digestible amino acids in the gut (Church, 1986). Ammonia, a byproduct of rumen fermentation, is the primary nitrogen source for ruminal bacteria. The supply of ammonia can be inadequate when either the intake of protein or the ruminal degradation of protein is low (NRC, 1984). Bacterial growth is reduced when ammonia is deficient, thus resulting in reductions in the rate and extent of digestion of feed in the rumen and possible reductions in feed intakes. The range of 6 to 8% CP has become a common standard from which to gauge the need for protein supplementation when feeding a particular feedstuff (DelCurto, 1991). In this survey, tall fescue, bentgrass and perennial ryegrass had higher mean CP levels as compared to orchardgrass and annual ryegrass (Table 3). However, these feeds are all deficient in protein and will require some form of protein supplementation.

Traditionally, grass seed straws were put in the same class as cereal grain straws as having low CP levels. In actuality, these levels are higher in comparison to cereal grain straws which range from two to four percent CP. Although grass seed straws have higher protein levels, these straws do require some form of protein supplementation, but the amount is relatively small as compared to that required for feeding cereal grain straws. The primary reason most grass seed straws have a higher protein level as compared to cereal grain straws is due to a greater leaf content in grass seed straws. Greater leaf to stem ratios are due, in part, to the fact that most grass seed species are perennial crops, whereas cereal grains are annual crops. Stems are often of a lower quality than leaves in mature forage (Van Soest, 1982) due to increases in lignified structures in stems as compared to leaves.

Acid Detergent Insoluble Nitrogen. Acid detergent insoluble nitrogen (ADIN) gives an indication of the amount of unavailable nitrogen in a particular feedstuff. It yields mainly lignified nitrogen and Maillard products (Van Soest, 1982). Grass seed straws in this survey had low levels of ADIN, even though straw is a highly lignified feedstuff. Tall fescue had the lowest mean ADIN levels, with perennial ryegrass, annual ryegrass and bentgrass being intermediate and orchardgrass having the highest levels of ADIN ($P<.05$; Table 4). Acid detergent insoluble nitrogen levels are expressed as a percentage of the total nitrogen in a sample. A higher percentage of the protein in these straws is available for microbial digestion. In addition, the ADIN levels reported in grass straws are comparable to low quality meadow or grass hays. Hunt et al. (1989), investigating the effects of cottonseed meal on digestion and performance of beef steers, reported a low-quality grass hay (CP 6.6%) basal diet having an ADIN fraction of 9.2%. Likewise, Gunter and co-workers (1990), evaluating the ruminal and forage intake responses of Holstein steers to supplementation on fescue hay, reported ADIN levels of 0.2%, but when expressed as a percentage of the total nitrogen, 22.5% of the nitrogen was unavailable in this fescue hay (6.1% CP). Krysl et al. (1987) found similar ADIN levels of .2% (expressed as a percentage of the total N content, 19.8%) in low-quality prairie hay. The nitrogen content of acid detergent fiber of forages is positively correlated with lignin content and negatively with digestibility; thus, digestibility of that particular feedstuff decreases, since increased lignification limits the fermentability of cellulose and hemicellulose by ruminal microbes (Van Soest, 1982).

Fiber Constituents: Neutral Detergent Fiber and Acid Detergent Fiber. Bentgrass, perennial ryegrass and tall fescue had similar NDF levels as compared to orchardgrass and annual ryegrass ($P<.05$; Table 5). Neutral detergent fiber measures plant cell wall constituents, such as cellulose, hemicellulose, and lignin, which are partially digestible due to microbial breakdown. Plant cell wall constituents are the primary determinant of intake potential (Van Soest, 1982; Fahey and Berger, 1988).

Acid detergent fiber components mirrored NDF; bentgrass had a lower percentage ADF as compared to the other four species, with orchardgrass and annual ryegrass having the highest ADF levels ($P<.05$; Table 6). Acid detergent fiber analysis digests the hemicellulose and cell wall proteins, leaving the cellulose, lignin and lignified nitrogen as a residue (Van Soest, 1982). This analysis indicates the relative digestibility of forages, with higher ADF levels being negatively correlated to digestibility (Van Soest, 1982; Fahey and Berger, 1988).

Because of their higher fiber levels, orchardgrass and annual ryegrass will have intake and palatability problems when utilized in ruminant diets. The physical characteristics of the diet influence ruminal fill, which in turn, has influence on feed intake. Feed intake is influenced by factors such as palatability, nutrient composition of a forage, age and the physiological or metabolic state of an animal (Galyean, 1987; Weston and Poppi, 1987). Orchardgrass and annual ryegrass straws are more coarse in texture which influences the acceptability by animals. Also, the amount of time undigested feed particles spend in the rumen plays a critical role in feed intake regulation (Weston and Poppi, 1987). Orchardgrass and annual ryegrass straws may have a longer retention time in the rumen due to increased levels of plant cell wall components; thus, the NDF fraction has the slowest rate of digestion as compared to the soluble cell wall contents (Fahey and Berger, 1988).

Other factors also influence retention time and digesta passage. Whether or not a close association can be formed between the microorganisms and their enzymes on feed is highly dependent upon the wetting of dry forages, fracturing of outer surfaces of plant tissues, increasing the surface area accessible for microbial attachment and removal of barriers, attachment inhibitors or more easily fermentable substrates (Mertens, 1987). An animal's chewing ability and particle size reduction through rumination and remastication also affect digesta passage, since particles must be a threshold size before they can pass through the reticulo-omasal orifice (Galyean, 1987). Chewing efficiency is decreased with increased dietary fiber content (Martz and Belyea, 1986) since higher fiber content requires more mastication even though the intake of high fiber diets is less than low fiber diets.

In vitro dry matter digestibility. In vitro dry matter digestibility measures the availability of feed to rumen bacteria or animal digestive enzymes; it is highly correlated to true digestibility (Van Soest, 1982). This procedure measures the total disappearance of feed (Owens and Goetsch, 1988). A buffer solution that simulates ruminant saliva and rumen fluid inoculum are mixed with a feed sample under anaerobic conditions and incubated for 48 h, simulating rumen digestion. After 48 h, the sample is centrifuged to remove the rumen fluid-saliva mixture and a pepsin-HCl solution is added to the feed sample and incubated for another 48 h to simulate small intestine digestion. The pepsin residue that remains is composed of undigested plant cell wall and bacterial debris (Van Soest, 1982). In this survey, perennial ryegrass and bentgrass had the highest in vitro dry matter digestibilities compared to annual ryegrass and orchardgrass, with tall fescue being intermediate ($P<.05$; Table 7). Therefore, as expected, straws that have a higher fiber content also displayed a lower digestibility.

Ergovaline concentration. Ergovaline is an ergopeptide alkaloid composed of a lysergic acid amide derivative (Yates, 1983; Bacon and DeBattista, 1991). It is produced by the fungal endophyte, *Acremonium coenophialum*. This endophyte has been introduced into some turf-type tall fescue and perennial ryegrass varieties because of the potential increases in plant hardiness, pest resistance and drought tolerance imparted by this fungus.

The amount of alkaloid present in an infected grass plant is dependent upon time of season, amount of fertilization, moisture, stage of maturity and variety (Yates, 1983). The distribution of the endophytic fungus changes over the length of the growing season. The fungus migrates from the seed into the developing grass seedling and in time, infects the stem and other leaf tissues (Bacon et al., 1986; Bacon and Siegal, 1988). As the plant matures and inflorescence develops, the fungus enters the ovule and eventually migrates into the newly formed seed (Bacon and Siegal, 1988). The highest concentrations of ergovaline are in seeds, leaf blades and sheaths, while some ergovaline is also present in the inflorescences and stems (Siegel et al., 1984; Lyons et al., 1986).

Ergovaline has been implicated in producing deleterious effects when consumed by livestock, particularly ruminant animals and horses. Effects on ruminants include lowered prolactin levels, increased respiration rates, long-dull-rough hair coats, lower feed intakes, lower weight gains, higher rectal temperatures, decreased heart rates, decreased skin surface temperatures of the extremities such as ears, tails and lower legs, fat necrosis, fescue foot, decreased ruminal fiber digestion and increased sensitivity to heat (Steen et al., 1979; Hemken et al., 1981; Stuedemann et al., 1985; Hannah et al., 1992; Osborn et al., 1992). In horses, alkaloid consumption has caused reproductive problems such as agalactia, thick placentas, spontaneous abortions, dead or weak foals at birth and rebreeding problems (Putnam et al., 1991). The feedstuffs utilized in these research studies have been seeds, moderate-to-good quality hays and pastures. No data exists on alkaloid content in grass seed straw.

In this survey, mean ergovaline concentrations for tall fescue and perennial ryegrass were 86 and 214 ppb, respectively. Of the fescue fields sampled, 14% had ergovaline levels greater than 200 ppb while 42% of the perennial ryegrass contained ergovaline levels greater than 200 ppb. A list of the tall fescue and perennial ryegrass varieties which showed measurable ergovaline levels is shown in Table 8. All the varieties in the table are turf-type grasses with the exception of Linn perennial ryegrass which is a forage-type grass. Identification of tall fescue and perennial ryegrass varieties that may contain high alkaloid levels is important when utilizing these straws as a feed. This research suggests high variation within varieties. For example, Titan tall fescue has a alkaloid concentration range from 105 to 945 ppb, with a standard deviation of $\pm$ 347.7. Thus, the identification of species varieties does not tell the whole story; there is a need to identify factors that influence ergovaline concentration beyond variety.

During the winter of 1991-92, feeding trials were conducted at the Eastern Oregon Agricultural Research Center in Burns to evaluate the effect of alkaloid concentration in high endophyte-infected tall fescue straw on beef steer nutrition, physiology and performance. This research is presented in the next chapter.

Implications

Based on this survey, bentgrass, perennial ryegrass and tall fescue had chemical compositions which indicate higher nutritional quality compared to orchardgrass and annual ryegrass. Bentgrass had favorable crude protein and fiber characteristics despite reaching maturity late in the season and higher rainfall. Orchardgrass and annual ryegrass had lower crude protein and higher fiber content which would limit intake and digestibility of these straws when used as feed. Perennial ryegrass has ergovaline alkaloid and the frequency of varieties containing greater than 200 ppb ergovaline is higher in perennial ryegrass as compared to tall fescue. Looking only at nutritional quality aspects, with proper supplementation, the residues from bentgrass, perennial ryegrass and tall fescue appear adequate for winter-feeding of spring-calving beef cattle.

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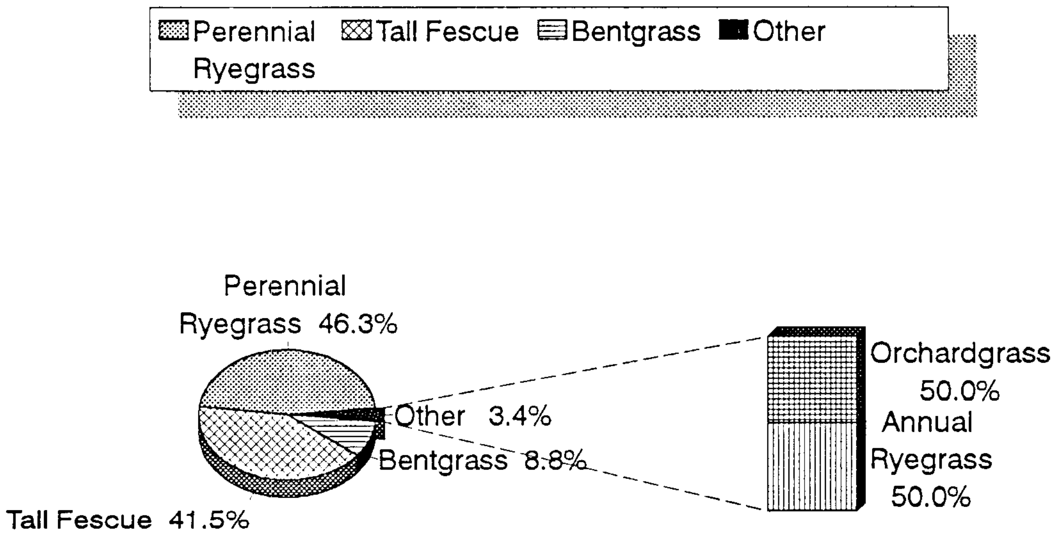

Figure 1. 1991 Grass seed straw survey: percent species composition of samples.

Table 2. Harvest factors which have an impact on nutritional quality of Willamette Valley grass seed straws

Species	Mean harvest date	Mean length from swathing until straw baling (days)	Mean Precipitation (cm)
Perennial Ryegrass	July 22	23.3	.6
Tall Fescue	July 12	20.7	.7
Bentgrass	August 4	19.9	1.2
Orchardgrass	July 8	11.5	.6
Annual Ryegrass	July 8	9.5	.5

Table 3. Crude protein (CP) levels in Willamette Valley grass seed straws (dry matter basis)

Species	Number of samples	Range (percent)	Mean[a] (percent)	Standard Deviation
Tall Fescue	122	3.7-8.9	5.6[b]	.90
Bentgrass	26	3.9-7.0	5.4[b]	.91
Perennial Ryegrass	136	3.6-9.4	5.3[b]	.88
Orchardgrass	5	3.7-5.7	4.8[c]	.95
Annual Ryegrass	5	4.3-5.2	4.7[c]	.35

[a] Pooled standard error of the mean = .18.
[b,c] Species means with differing subscript differ ($P<.05$).

Table 4. Acid detergent insoluble nitrogen (ADIN) levels in Willamette Valley grass seed straw (dry matter basis)[a]

Species	Number of samples	Range (percent)	Mean[b] (percent)	Standard Deviation
Tall Fescue	122	7.3-20.7	12.8[c]	2.63
Perennial Ryegrass	136	5.1-23.0	15.5[c,d]	3.03
Annual Ryegrass	5	12.6-22.8	16.4[c,d]	4.17
Bentgrass	26	13.1-25.3	16.6[c,d]	2.69
Orchardgrass	5	15.6-21.4	18.4[d]	2.57

[a] ADIN expressed as a percent of total nitrogen.
[b] Pooled standard error of the mean = .81.
[c,d] Species means with differing superscripts differ ($P<.05$).

Table 5. Neutral detergent fiber (NDF) levels in Willamette Valley grass seed straw (dry matter basis)

Species	Number of samples	Range (percent)	Mean[a] (percent)	Standard Deviation
Bentgrass	26	56.6-76.3	63.7[b]	3.71
Perennial Ryegrass	136	60.5-74.2	65.8[b]	2.79
Tall fescue	122	62.1-76.6	67.9[b]	3.19
Orchardgrass	5	64.3-70.6	68.2[b,c]	2.75
Annual Ryegrass	5	65.3-80.5	72.8[c]	6.97

[a] Pooled standard error of the mean = 1.12.
[b,c] Species means with differing superscripts differ ($P<.05$).

Table 6. Acid detergent fiber (ADF) levels in Willamette Valley grass seed straw (dry matter basis)

Species	Number of samples	Range (percent)	Mean[a] (percent)	Standard Deviations
Bentgrass	26	34.1-40.8	37.9[b]	1.68
Perennial Ryegrass	136	37.9-49.0	41.6[c]	2.05
Tall Fescue	122	39.9-52.9	43.8[c]	2.50
Orchardgrass	5	46.2-49.9	47.2[d]	1.52
Annual Ryegrass	5	41.8-52.0	47.8[d]	4.84

[a] Pooled standard error of the mean = .72.
[b, c, d] Species means with differing superscripts differ (P<.05).

Table 7. In vitro dry matter digestibility (IVDMD) of Willamette Valley grass seed straws

Species	Number of samples	Range (percent)	Mean[a] (percent)	Standard Deviation
Perennial Ryegrass	136	43.5-61.5	55.5[b]	3.28
Bentgrass	26	47.7-59.5	55.0[b]	3.24
Tall Fescue	122	36.3-62.4	53.9[b]	4.14
Annual Ryegrass	5	46.5-56.4	51.1[b,c]	3.86
Orchardgrass	5	46.1-50.7	48.7[c]	1.87

[a] Pooled standard error of the mean = .77.
[b,c] Species means with differing superscripts differ (P<.05).

Table 8. Ergovaline content of Tall Fescue and Perennial Ryegrass varieties[a]

Species	Variety	Number of samples	Range (ppb)	Mean (ppb)	Standard Deviation
Tall Fescue	Arid	8	0-115	35.6	50.1
	Clemfine	3	0-345	201.7	179.8
	Falcon	9	0-130	33.3	48.3
	Mustang	5	85-140	102	22.0
	Rebel II	4	25-210	118.8	75.7
	Titan	6	105-945	551.7	347.7
	Tribute	3	365-680	511.7	158.6
	Trident	5	56-194	123.4	50.9
Perennial Ryegrass	C-21	6	0-90	44.7	37.1
	Charger	4	55-200	128.8	69.7
	Cowboy	4	185-500	362.5	141.8
	Dasher II	3	80-765	386.7	348.1
	Envy	3	60-85	70	13.2
	Fineleaf	5	50-225	109.6	71.5
	Linn	4	75-210	118.8	62.8
	Manhattan II E	4	390-790	582.5	199.5
	Palmer	5	105-185	129	32.3
	Pinnacle	3	0-430	181.7	222.6
	Pennant	3	33-425	196	204.2
	Premiere	6	0-440	111.3	165.5
	Riveria	3	400-410	405	5.0
	Seville	3	393-645	502.7	129.1
	SR 4100	5	255-550	378	111.6
	SR 4200	4	240-450	338.8	86.3
	Sunrye	6	0-478	270.5	183.2

[a] Only varieties with three or more samples are reported here.

INFLUENCE OF ALKALOID CONCENTRATION OF TALL FESCUE STRAW ON THE NUTRITION, PHYSIOLOGY AND SUBSEQUENT PERFORMANCE OF BEEF STEERS

Introduction

The presence of the fungal endophyte, *Acremonium coenophialum*, in tall fescue (*Festuca arundinacea* Schreb.), has been implicated in reduced animal performance and fescue toxicosis. Jacobson et al. (1970) reported reduced weight gains as well as higher respiration rates and increased rectal temperatures. Other symptoms of fescue toxisosis include rough hair coats, increased salivation, nervousness and overall reduced performance (Hoveland et al., 1983). Recommendations of diluting fescue diets or grazing fescue after the growing season have been utilized effectively to avoid endophyte related problems.

In the Pacific Northwest, a large volume of tall fescue grass seed residue is produced (> 200,000 metric tons) and has potential use as a winter feedstuff, but concern over the presence of the endophyte and nutritional quality has curtailed its utilization. To date, most of the endophyte alkaloid research has focused on forages, seeds and moderate-to-good quality tall fescue hays. No research has been conducted to evaluate the feeding of straw with high alkaloid concentrations and its subsequent effect on animal performance. In addition, very little is known about whether the consumption of a high-endophyte containing straw by cattle during the winter can induce fescue toxicosis symptoms, specifically vasoconstriction of the extremites. Therefore, this research was conducted to evaluate the effect of alkaloid concentration in feeding high endophyte-infected tall fescue straw on nutrition, physiology and subsequent performance of beef cattle.

Materials and Methods

Harvesting and Treatment of Residues. Two varieties of Tall Fescue straw (Bonanza and Titan turf-type) were selected to assess endophyte effects on beef cattle nutrition and performance. The two varieties were similar genetically and phenotypically, but differed in alkaloid concentrations. The Bonanza straw came from a third year stand and was baled 15 d post seed harvest. The Titan straw came from a second year stand and was baled 27 d post harvest. Both varieties were grown in the Willamette Valley of Oregon and are common varieties grown for seed crop production. Windrows were not raked before baling. Both straw varieties were stored in hay sheds until being trucked to Burns, after which bales were stored in stacks until chopping and feeding occurred. Bale weights averaged 32 kg. Straw was chopped every three weeks and stored in covered hay sheds. Because the two varieties of tall fescue straw differed in CP concentration (avg CP 7.1% and 4.9% for Titan and Bonanza, respectively), second cutting alfalfa (CP = 18.9%) was chopped and mixed with the Bonanza straw (16% Alfalfa to 84% Bonanza Tall Fescue) to ensure isonitrogenous diets. Chemical analysis of the straws composited across time are listed in Table 9. Samples of each straw were analyzed by high performance liquid chromatography (HPLC) for ergovaline content. The Titan straw contained 475 ppb and 0 ppb for Bonanza.

Exp. 1, Digestion/Physiology Study. In early February 1992, sixteen ruminally cannulated steers (avg wt = 370 kg) were used in a randomized complete block design. Steers were blocked by age and weight and, within blocks, randomly assigned to the following treatments: 1) 100% Titan; 2) 67% Titan-33% Bonanza; 3) 33% Titan-67% Bonanza and 4) 100% Bonanza. The basal diets of straw for treatments one through four, in order, contained 475, 317, 158 and 0 ppb ergovaline. Steers were given ad libitum access to the basal straw diets and supplemented with alfalfa pellets at .5% of BW of individual steers. This 36 d digestion study involved a 21 d adaptation period, 7 d intake period, 6 d of total fecal collections, one d of rumen profiles, and one d of rumen evacuations, respectively. Physiological parameters were also measured weekly at 1300 h to determine physiological response to ergovaline: rectal temperatures, skin surface temperatures by an infrared thermometer (Everest Interscience, Tustin, CA.) of the tailhead (underside) and the ear (between the second and third rib), heart rates (area behind the left front elbow) and respiration rates were recorded. In addition, weekly blood samples were also collected via jugular venipuncture into vacutainer tubes for prolactin (PRL) analysis. Blood samples were allowed to clot at room temperature overnight and then were centrifuged (International Centrifuge, Boston, MA.) the next morning to remove the serum. Samples were centrifuged at 1,000 *g* for 10 minutes and serum was removed and frozen at -20^{o} C until further analysis. Ambient barn temperatures were also measured during the study; minimum temperatures recorded at 0700 h and maximum temperatures at 1700 h. The average minimum and maximum temperatures were 1.2^{o} C and 11.1^{o} C, respectively and ranged from -3.3^{o} C to 18.9^{o} C. Intake and orts were measured daily during the duration of the study and were subsampled beginning on d 22 for dry matter and nutrient content determination. On d 28, fecal harnesses and bags were attached to the steers. Fecal bags were weighed, emptied and subsampled daily at 1500 h. A 2.5% fecal subsample was dried and ground to pass through a 1 mm Wiley mill screen. On d 35, rumen fluid samples were taken at 0 h (prior to feeding), 3, 6, 9, and 12 h (post feeding); fluid samples were analyzed for pH, ammonia and volatile fatty acid content. On d 36 at 0800 and 1400 h, each steer was emptied of reticulo-rumen contents. The contents were weighed, thoroughly mixed and subsampled in triplicate to determine DM digesta kinetics. On d 39 and 40, two blocks of steers (8 animals) were subjected to a thryotropin releasing hormone (Sigma Chemical Company, St. Louis, MO.) challenge (TRH) to measure PRL stores in the pituitary. The steers were catheterized in the jugular vein the afternoon before or morning of the challenge with Radiopaque FEP teflon I.V. catheters (Abbott Hospital, Inc., North Chicago, IL.). Each steer was dosed with a 100 *u*g TRH injection via jugular catheter. Blood samples were collected starting at 1030 h at -30, -15, 0 (before adminitraion of TRH), and 15, 30, 45, 60, 90, 120, 150 and 180 min (post TRH administration). Catheters were kept clot-free by injections of a physiological saline-sodium citrate-benzyl alcohol solution. Blood samples derived during the TRH challenge were allowed to clot at room temperature overnight and then refrigerated until centrifuging for serum removal. Samples were centrifuged at 1,000 *g* for 10 min and the serum was frozen at -20^{o} C until further analysis.

Exp. 2, Performance Study. Eighty-four Hereford x Angus steers (avg wt = 220 kg) were allotted into one of three weight blocks (light, medium and heavy) and within weight blocks, randomly assigned to the same above treatments (7 steer/pen) for an 84 d performance trial. All the steers were supplemented with alfalfa pellets at .5% BW of the average pen weight. Pens were fed forage daily and feed refused was weighed back and subsampled weekly. Every 28 days steers were weighed after a 16 h shrink to measure weight gains and feed efficiencies. One steer on the 100% Titan straw died on d 46 of the performance trial. Necropsy on the steer suggested there was no relationship between the animal's death and treatment or alkaloid effects. Weight gain data for this steer was omitted from the final statistical analysis.

Laboratory Analysis and Calculations. Feed, ort, fecal and rumen evacuation samples were dried at 60^{o} C in a forced-air oven. Equal amounts of feed offered, 10% of daily orts and 2.5% of daily feeds were composited and ground to pass a 1 mm Wiley mill screen. Ground straw and supplement samples were analyzed for DM and Kjeldahl N (AOAC, 1984), ADF and NDF (Goering and Van Soest, 1970). Acid detergent insoluble N (ADIN) was calculated by Kjeldahl N on the ADF residue (Goering and Van Soest, 1970). Indigestible acid detergent fiber (IADF) was also determined (Cochran et al., 1986) to measure an indigestible component of all diets. Ergovaline analysis of the feeds was completed at the University of Missouri by Dr. George Rottinghaus. Ruminal pH was determined using a combination electrode (AOAC, 1984). After treating ruminal fluid samples with 0.1 N HCl (5 ml acid to 5 ml rumen fluid) and 25% metaphosphoric acid (2 ml acid to 8 ml rumen fluid), samples were frozen at -20^{o} C until analysis for VFA and ammonia concentrations. Volatile fatty acid analysis was performed using a fused silica capillary column (Alltech Associates, Inc., Deerfield, IL.) in a gas chromatograph (5890 Series II gas chromatograph; Hewlitt Packard Co., Analytical group, San Fernando, CA). Ammonia determination was conducted using the phenol hypochlorite assay (Broderick and Kang, 1980) and samples were analyzed by a narrow-band spectophotometer (Varian 634 spectophotometer; Varian Techtron Pty. LTD., Springvale, Australia) at 630 nm.

All PRL analysis was conducted at the New Mexico State University Endocrinology Laboratory using an RIA procedure (assay materials supplied by NIDDK) as described by Spoon and Hallford (1989). All samples were assayed in a single run with a coefficient of variation of 9.3% When 25 ng PRL was added to 1.0 ml serum containing 15.9 ng PRL, 40.1 $\pm$ 1.1 ng/ml was recovered (98%, n=12).

Statistical Analysis. In Exp. 1, intake, DM digestibility (DMD) and digesta kinetics were analyzed as a randomized complete block design using the General Linear Models (GLM) of Statistical Analysis Program for personal computers (SAS, 1987). Individual animals were considered the experimental unit. Treatment means were separated using orthogonal contrast statements comparing the varying levels of Titan tall fescue straw in the diets. Physiological data, weekly prolactins, pH, VFAs, ammonia and TRH challenge prolactins were analyzed as a randomized complete block design, split plot in time with respect to corresponding sampling dates or times. When treatment x time interactions occurred ($P<.10$), treatment means were analyzed within time periods and are presented graphically. In Exp.2, intake, weight gain and feed/gain rations were analyzed as a randomized complete block design using orthogonal contrast statements to separate the means. Because animals were pen fed, pen was considered the experimental unit.

Results and Discussion

Exp. 1, Digestion/Physiology Study. Neither forage nor total DMI were affected by treatment; diet intakes averaged 6.0 kg and 7.7 kg, respectively ($P>.10$). Total intakes on a percent body weight basis averaged 2.1% (Table 10). Apparent DMD was similar for all four diets across treatments, ranging from 46% to 48.8%, and NDF digestion did not differ among diets ($P>.10$). These results are similar to a study by Forcherio et al. (1992) who evaluated energy and protein supplementation effects on digestion of endophyte-infected tall fescue hay. They reported no differences in either hay or total DMI among the six treatments ($P>.05$) and saw similar total tract digestibility values for the four supplements. Likewise, Peters et al. (1992) also saw no differences in forage intake by beef cows grazing endophyte-infected and endophyte-free tall fescue pastures (P>.10) during a two year study.

Digestion Kinetics. Small differences were seen in digesta kinetics. Digesta fill for the 0800 h evacuation showed a quadratic response (P<.10), but no difference (P>.10) for the 1400 h evacuation (Table 11). Indigestible ADF fill for both evacuations and IADF outflow increased with decreasing alkaloid levels (P<.10), although passage rates were not different across treatments (P>.10). This may be attributed to the physical nature of the basal diets rather than differences related to alkaloid concentration per se. Indigestible ADF content of Titan and Bonanza tall fescue were 23.4% and 28.0%, respectively. Thus, with similar DM intakes and DM fills, IADF fill and outflow changed as one variety was increased at the expense of the other.

Changes in rumen kinetics due to the presence of the endophyte have been reported in the literature. Goetsch et al. (1987) found a linear increase in NDF total tract digestion as the percentage of endophyte-infected hay in the diet increased. In addition, they also reported linear and quadratic changes in ruminal passage rates of particulates due to increased levels of endophyte-infected hay. In diets containing 3 ppm ergovaline, Hannah and co-workers (1990) reported ruminal and total tract OM, NDF and cellulose digestibilities were less than when diets contained 0 ppm ergovaline concentrations. They also saw greater ruminal fluid dilution rates and fluid outflow due to the higher ergovaline concentration. These levels of ergovaline are more concentrated than the ergovaline concentrations reported in this study. In addition, the ergovaline concentration in the previous study was derived from ergovaline-infected tall fescue seed, which is higher in digestibility as compared to these diets. Because of this, an increased amount of alkaloid may be absorbed, thus resulting in a greater impact on rumen digestion.

Rumen Profile. Ruminal pH showed a quadratic response (P<.10) across the four treatments (Table 12). Ammonia concentrations did not show a treatment difference (P>.10) and averaged below 5 mg/dL. Previous research has suggested with less than 5 mg/dL of NH_3 -N, rumen digestion becomes limited due to a deficiency of available nitrogen for microbial biosynthesis, since the maximum concentration of ruminal ammonia needed to reach maximum microbial protein production was 5 mg/dL (Satter and Slyter, 1974). In terms of total VFAs, treatments showed a linear response (P<.10); total VFA amounts increased as the amount of Titan straw increased in the diet. Acetate, isobutyrate and isovalerate decreased (P<.10) and butyrate increased (P<.10) linearly in concentration as the amount of Titan increased in the diets. Since these VFAs did not show a treatment x time response, mean values were averaged across time and are shown in Table 12. Propionate and the acetate to propionate ratios displayed a treatment x time interaction (P<.10). At 6 h post feeding, propionate levels exhibited a quadratic response (P<.10) with the 100% Titan and O% Titan diets having a higer percentage of propionate. At 9 h post feeding, propionate levels had a linear response (P<.01) across treatments; diets higher in Titan had a higher percentage and at 12 h post feeding, propionate levels exhibited a quadratic response (P<.10), with 100% Titan having the highest percentage, followed by 67% and 0% Titan diets and 33% Titan diets having the lowest percentage . The acetate to propionate ratios also showed a quadratic response (P<.10) at 6 h post feeding, with the intermediate Titan diets having the highest ratios. At 9 h post feeding, ratios illustrated a linear response (P<.10); the 0% Titan diet had the greatest ratio, followed by the intermediate Titan diets. At 12 h post feeding, 33% Titan diet had the greatest ratio, followed by 67% and 0% Titan. The 100% Titan diet had the lowest ratio of acetate to propionate over time (Figure 2). Increased propionate production during rumen digestion is indicative of more efficient ruminal fermentation (Owens and Goetch, 1988). Although total tract digestion was similar across the four treatments, these results would suggest that the Titan straw was higher in nutritional quality than the Bonanza straw.

Physiological Response. In regards to the physiological parameters, no treatment x time interaction occurred (P>.10), so the means were averaged across time

(Table 13). Heart rate, respiration rate, rectal, tail and ear temperatures were similar across treatments (P>.10). These results resemble findings by Hemken et al. (1981) in which no differences in DMI, rectal temperatures and respiration rates occurred when Holstein calves were fed an endophyte-infected tall fescue forage at ambient temperatures below 32^{o} C. Likewise, Ghorbani et al. (1989) also found no significant difference in daily feed intakes, rectal temperatures, respiration rates, serum PRL levels and ADG when feeding varying amounts of endophyte-infected tall fescue hay at environmental temperatures of 31-32^{o}C (50% humidity). Osborn and co-workers (1992) reported similiar findings of no effect to cattle from consumption of an endophyte-infected fescue diet at temperatures of 21^{0} C. However, at temperatures of 32^{o}C, they found that animals fed either the endophyte-infected fescue or a fungus-free fescue diet mixed with 30 ppm ergotamine tartrate exhibited symptoms of fescue toxicosis: feed intakes, heart rates, infrared temperatures of the ear canal, pastern, coronary band and tail tip had all decreased, with rectal temperatures and respiration rates showing elevated levels.

Weekly PRL levels decreased linearly across treatment means (P<.10) as the levels of Titan increased in the diet. Goetsch and co-workers (1987) reported similar findings of a linear decrease in PRL levels when feeding increasing levels of endophyte-infected fescue hay to growing dairy steers. The magnitude of change in their study was similar to those in this study; PRL levels were 15, 11.2, .1, .8 and 0 ng/ml for 0, 25, 50, 75 and 100% infected fescue hay, respectively. However, at high levels of endophyte infection, Goetsch et al. reported no circulating PRL levels as compared to this study which had measurable circulating PRL levels.

The levels of PRL reported in this study are lower than other levels reported for beef cattle in the literature. This can be attributed to minimal ambient temperatures and a shortened daily photoperiod which occurs during winter, causing ruminants to have lower serum PRL as compared to spring or summer, when increases in temperature and photoperiod elevate serum PRL levels (Peters and Tucker, 1978). The PRL levels in this study, however, are comparable to serum PRL levels reported for cooler temperatures. Smith and co-workers (1977), investigating the effect of altering ambient temperatures on serum PRL, measured PRL levels at 4.6 ng/ml at $4^{O}C$ in Hereford steers. In addition, they also discovered that PRL recovered slowly as temperature was elevated. After 60 minutes at $18^{O}C$, serum PRL levels only averaged 5.2 ng/ml in these steers.

All the steers in this study responded to the TRH challenge; the magnitude of response was similar across treatments and not affected by alkaloid level (P>.10). Since no treatment x time interaction occurred (P>.10), treatment means were averaged across time. Maximum temperature for both days of TRH challenge was $13.3^{O}C$, well within the thermal neutral zone of cattle. The highest concentration of PRL (34.3 ng PRL/ml) occurred thirty minutes after the administration of TRH (Figure 3), after which PRL levels returned towards baseline values.

Past research has indicated that TRH stimulated PRL levels will be suppressed or reduced in animals consuming high endophyte diets. Thompson and co-workers (1987), investigating the effects of high endophyte fescue upon serum PRL throughout a grazing season, reported depressed levels for both basal and TRH stimulated PRL levels in yearling Angus steers. Lipham et al. (1989) also found similar results of PRL suppression as well for basal and TRH induced PRL levels in yearling Angus steers grazing a high endophyte-infected fescue. Hurley et al (1981) reported reduced basal PRL concentrations in steers feed GI-307 at three temperature ranges tested, including temperatures of $10\text{-}13^{O}C$. They suggested that the toxic components of toxic fescue (GI-307) were active at all temperatures, not just in instances of elevated temperatures. Upon TRH administration, they found PRL releases were affected by both temperature and forage, with the steers consuming the GI-307 fescue having lower PRL levels at all three temperature ranges tested (low $10\text{-}13^{O}C$, medium 21 to $23^{O}C$ and high 34 to $35^{O}C$). In contrast, Hohenboken and co-workers (1991) also reported finding a tendancy for PRL suppression to occur after administering TRH to cows on fescue seed diets, but this response was sensitive to ambient temperatures. During one bleeding sequence, they found that the environmental conditions (warm temperatures and humid conditions) overrode and prevented this suppression from occurring .

Exp. 2, Performance study. Forage intake and total intakes illustrated a linear response ($P<.10$); intakes increased with decreasing alkaloid levels (Table 14). However, steer weight gains and feed/gain ratios did not differ ($P>.10$), averaging 14.0 kg and 16.2 kg, respectively. Since weight gains and feed efficiencies were fairly similar across treatments, the differences in intake may be attributed to palatability differences due to the presence of alfalfa hay in the Bonanza straw. No adverse health effects were seen during the performance trial, although 100% Titan steers were consuming 2 mg/d ergovaline. On a kg of BW basis, these steers were consuming 9.10 *u*g ergovaline/kg of BW per day. This value is comparable to the ergovaline levels consumed by mature cows in the study conducted by Peters et al. (1992) in which cows were consuming 8.5 ug ergovaline/kg of BW and 11.7 ug ergovaline/kg of BW on a daily basis for 1988 and 1989, respectively.

Absence of negative effects in feeding high endophyte fescue in these studies may be due to lack of environmental stress and/or the physical composition of the straw. Both trials were conducted at average ambient maximum temperatures of 9^{o}C in an arid environment. Hannah et al (1990) reported no difference among diet treatments contrasting levels of ergovaline up to 20 ppm in areas of intake and ruminal kinetics when lower ambient temperatures and humidity occurred. Likewise, Peters et al. (1992) also experienced no differences in OM intakes during their two year study in which temperatures near 32^{o}C occurred although the cows were consuming between 4.2 mg/d and 6.0 mg/d ergovaline for years one and two, respectively. However, Peters et al. (1992) did observe depressions in cow and calf gains on high endophyte-infected tall fescue pasture. Their study utilized a more highly digestible feedstuff (pasture forage) which may have increased the chances of reduced performance and(or) other associated problems occurring. Straw, with its more fibrous physical nature, has a longer retention time in the rumen and is not as highly digestible as seeds and(or) forages where classical symptoms of fescue syndrome and(or) reduced performance are observed. Thus, although straw may have concentrations of alkaloids similar to these feeds, decreased intake digestion and subsequent host animal absorption of alkaloids may be lower, reducing the risk of toxicity problems or reduced gains.

Implications

Under the conditions of these studies, the endophyte-produced alkaloids associated with tall fescue straw did not cause health problems or reductions in animal performance. Dry matter intakes and digestive efficiencies were similar across treatments. In addition, no evidence of vasoconstriction or other physiological symptoms associated with fescue toxicosis were observed. However, circulating PRL levels were decreased with high endophyte straw diets, indicating a possible subclinical effect. Further research is needed to evaluate the effects of high endophyte straw diets on late gestating and lactating beef cattle. Therefore, these studies suggest that properly supplemented low-quality straws up to 475 ppb ergovaline can be fed in winter feeding programs for growing and early to mid gestating cows without depression in animal health, nutrition or performance.

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Table 9. Chemical Composition[a] of feeds (Exp. 1 and 2)

Item	Titan	Bonanza	Alfalfa pellets
CP, %	6.3	5.3	19.4
ADIN[b], %	9.4	11.6	5.5
NDF, %	67.4	71.1	50.5
ADF, %	44.6	49.2	34.1
IADF[c], %	23.4	28.0	20.5
Ergovaline, ppb	475	0	

[a] Chemical compostion expressed on a DM Basis.
[b] Expressed as a % of total nitrogen.
[c] IADF = indigestible acid detergent fiber.

Table 10. Dry matter intake and total tract digestion of beef steers consuming graded levels of high endophyte tall fescue

	% Titan tall fescue					Orthogonal contrasts		
Item	0	33	67	100	SE[a]	Linear	Quadratic	Cubic
DM intake, kg								
Forage	6.2	5.8	5.7	6.3	.33	.97	.18	.92
Total	7.9	7.5	7.4	7.9	.32	.99	.20	.81
DM intake, % BW								
Forage	1.7	1.5	1.6	1.7	.09	.84	.14	.85
Total	2.1	2.0	2.0	2.2	.09	.84	.14	.86
Apparent DMD, %	46.0	48.0	47.0	48.8	1.16	.19	.91	.29
NDF digestion, %	44.0	44.0	42.8	44.3	1.35	.94	.94	.52

[a] Standard error, n = 4.

Table 11. Digestive kinetics[a] for beef steers consuming graded levels of endophyte infected tall fescue straw

	% Titan tall fescue					Orthogonal contrasts		
Item	0	33	67	100	SE[b]	Linear	Quadratic	Cubic
Digesta fill DM, kg								
0800	7.9	7.2	6.1	6.9	.38	.04	.08	.17
1400	10.8	10.2	9.3	10.1	.53	.24	.26	.42
Liquid, *l*								
0800	54.1	55.0	49.3	50.9	2.19	.15	.86	.18
1400	71.2	72.9	67.5	66.3	3.62	.25	.69	.49
IADF fill, g								
0800	3770	3510	3340	3250	200	.08	.67	.98
1400	4660	4230	3620	4010	200	.02	.07	.23
IADF outflow, g	100	80	80	80	5	.008	.10	.73
IADF passage, %/h								
0800	2.5	2.3	2.3	2.4	.17	.68	.34	.96
1400	2.0	1.9	2.1	1.9	.11	.86	.73	.22

[a] Digesta kinetics was based on rumen evacuations just prior to feeding (0800) and 5 h post-feeding (1400).
[b] Standard error, n = 4.

Table 12. Rumen fluid profile for beef steers consuming graded levels of endophyte infected tall fescue straw

	% Titan tall fescue					Orthogonal contrasts		
Item	0	33	67	100	SE[a]	Linear	Quadratic	Cubic
pH	6.6	6.6	6.6	6.5	.03	.01	.07	.04
Ammonia mg/dl	4.8	5.1	4.7	4.5	.21	.18	.32	.36
Total VFA (Mm)	120.5	126.2	121.3	136.6	4.7	.06	.33	.17
	---------- mol / 100 mol ----------							
Acetate	72.8	72.6	72.4	70.7	.40	.01	.12	.41
Isobutyrate	.76	.74	.70	.59	.03	.001	.14	.71
Butyrate	7.0	7.3	7.5	8.4	.20	.001	.15	.41
Isovalerate	.63	.59	.56	.45	.04	.01	.46	.72
Valerate	.82	.77	.80	.85	.03	.30	.13	.63

[a] Standard error, n = 4.

Table 13. Physiological response of beef steers consuming graded levels of endophyte infected tall fescue straw

	% Titan tall fescue					Orthogoal contrasts		
Item	0	33	67	100	SE[a]	Linear	Quadratic	Cubic
Heart rate beats/min	59.4	62.2	62.8	58.9	2.3	.93	.18	.82
Respiration Rate breaths/min	15.4	15.8	16.3	14.3	.87	.47	.22	.51
Temperatures								
Rectal, ^{o} C	38.5	38.6	38.4	38.5	.06	.24	.60	.13
Tail head, ^{o}C	35.8	35.8	36.1	35.3	.20	.23	.11	.16
Inner ear, ^{o}C	25.8	26.2	27.1	27.7	.91	.15	.93	.87
Weekly PRL ng/ml	15.4	18.8	6.7	5.5	5.0	.09	.66	.27
TRH-challenge PRL, ng/ml	8.14	23.0	11.4	6.3	6.0	.54	.13	.25

[a] Pooled standard error, n = 3.

Table 14. Performance data for beef steers consuming graded levels of endophyte infected tall fescue

	% Titan tall fescue					Orthogoal contrasts		
Item	0	33	67	100	SE[a]	Linear	Quadratic	Cubic
Forage intake, kg	4.8	4.3	4.3	4.2	.18	.07	.34	.68
Total intake, kg	5.8	5.4	5.3	5.3	.08	.08	.35	.68
Weight gain, kg	14.4	13.1	12.9	14.5	.98	.98	.50	.94
Feed/gain, kg	16.0	16.0	17.8	15.0	.93	.93	.61	.61

[a] Pooled standard error, n = 3.

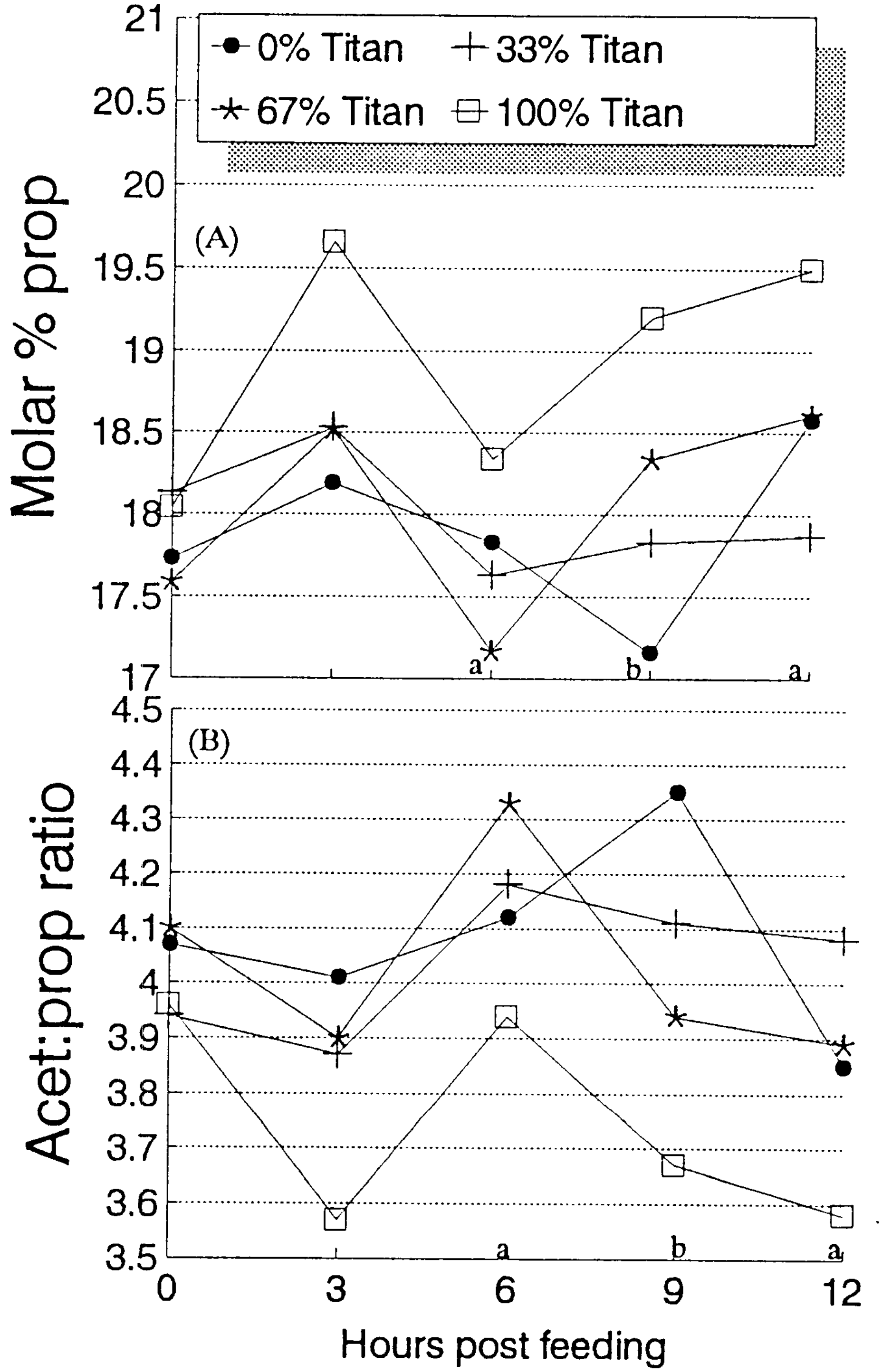

Figure 2. Influence of graded levels of endophyte-infected tall fescue straw on the molar proportion of ruminal propionate (A) and acetate to propionate ratios (B; Exp. 1). Quadratic [a] (P<.10) and linear [b] (P<.01) differences among treatment means within time periods are denoted along the x-axis. Standard errors within time periods ranged from .33 to .56 and .10 to .16 for ruminal propionate and acetate to propionate ratios, respectively.

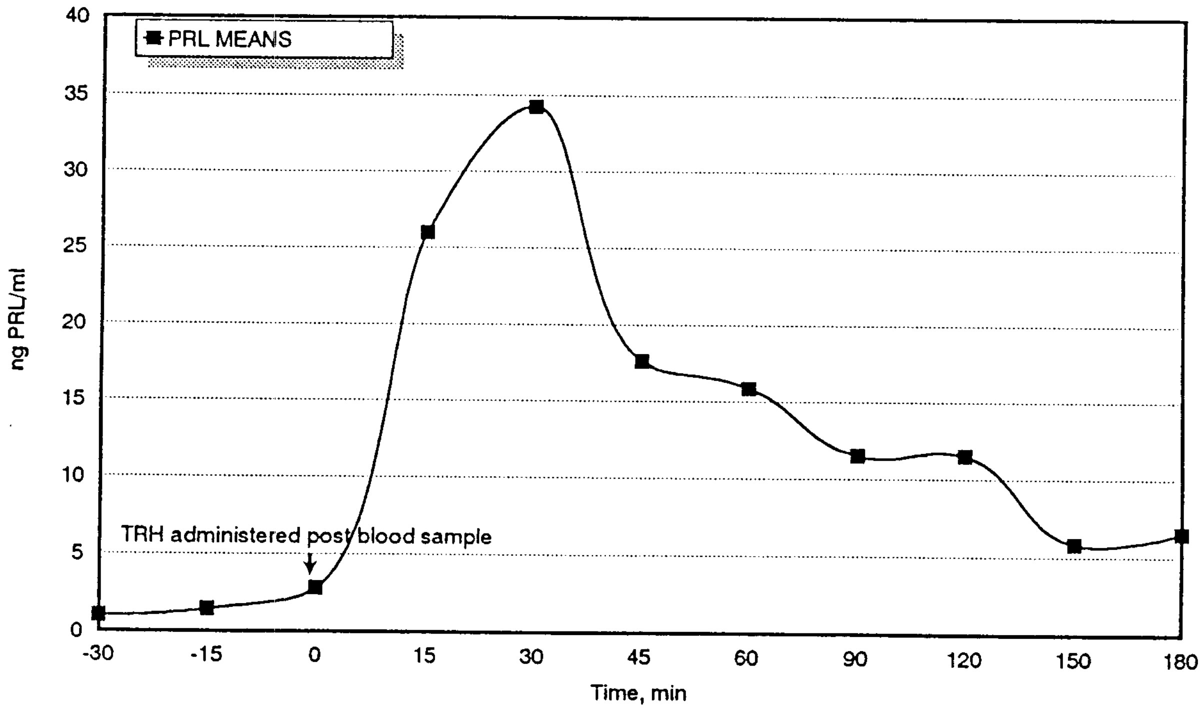

Figure 3. Thyrotropin-releasing hormone (TRH) stimulated PRL response curve in beef steers consuming graded levels of endophyte-infected tall fescue straw.

APPENDIX

List of Acceptable Abbreviations Used in the Journal of Animal Science

Physical Units:

Bq	Becquerel
°C	degree Celsius
cal	calorie
Ci	Curie
Da	Dalton
dpm	disintegrations/minute
g	gram
ha	hectare
IU	International unit
J	Joule
L	Liter
lx	lux
m	meter
M	molar (concentrations)
mol	mole
N	normal (concentrations)
Pa	Pascal
ppb	parts/billion parts
ppm	parts/million parts
t	metric ton (1,000 kg)
W	Watt

Prefixes:

G	giga- (x 10^{9})
M	mega- (x 10^{6})
k	kilo- (x 10^{3})
d	deci- (x 10^{-1})
c	centi- (x 10^{-2})
m	milli- (x 10^{-3})
u	micro- (x 10^{-6})
n	nano- (x 10^{-9})
p	pico- (x 10^{-12})
f	femto- (x 10^{-15})

Units of Time:

s	second
min	minute
h	hour
d	day
wk	week
mo	month
yr	year

Others:

ACTH	adrenocorticotropic hormone
ADFI	average daily feed intake
ADIN	acid detergent insoluble nitrogen
ADP	adenosine diphosphate
AIA	acid insoluble ash
ARS	agricultural research service
avg	average
BSA	bovine serum albumin
CP	crude protein (N x 6.25)
DE	digestible energy
df	degree of freedom
DMI	dry matter intake
EBV	estimated breeding value
EFA	essential fatty acid
ADF	acid detergent fiber
ADG	average daily gain
ADL	acid detergent lignin
AI	artificial insemination
ANOVA	analysis of variance
ATP	adenosine triphosphate
BLUP	best linear unbiased prediction
BW	body weight
CV	coefficient of variation
DEAE	(dimethylamino)ethyl
DM	dry matter
DNA	deoxyribonucleic acid
EDTA	ethylenediaminetetraacetic acid
e.g.,	for example

List of Acceptable Abbreviations Used in the Journal of Animal Science (continued)

Others (continued):

ELISA	enzyme-linked immunosorbent assay	EPD	expected progeny difference
et al.,	et alia	etc.	et cetera
Exp.	experiment	FSH	follicle-stimulating hormone
g	gravity	GE	gross energy
GLC	gas-liquid chromatography	GLM	General Linear Model
GnRH	gonadotopin-releasing hormone	hCG	human chorionic gonadotropin
HEPES	N-(2-hdroxyethyl)piperazine-*N*'-2-ethanesulfonic acid	HPLC	high performance (pressure) liquid chromatography
i.d.	inside diameter	i.e.,	that is
i.m.	intramuscular	i.v.	intravenous
IVDMD	in vitro dry matter disappearance	LD_{50}	lethal dose 50%
LH	luteinizing hormone	LHRH	luteinizing hormone-releasing hormone
lsd	least significant difference	ME	metabolizable energy
n	number of samples	NDF	neutral detergent fiber
NE	net energy	NE_g	net energy for gain
NE_l	net energy for lactation	NE_m	net energy for maintenance
No.	number	o.d.	outside diameter
OM	organic matter	*P*	probability
PAGE	polyacrylamide gel electrophoresis	PBS	phosphate-buffered saline
r	coefficient of determination	r^2	coefficient of determination
R^2	multiple coefficient of determination	REML	restricted maximum likelihood
RIA	radioimmunoassay	RNA	ribonucleic acid
rpm	revolutions/minute	s.c.	subcutaneous
SD	standard deviation	SDS	sodium dodecyl sulfate
SE	standard error	SEM	standard error of the mean
sp., spp.	one species, several species	TDN	total digestible nutrients
TLC	thin lay chromatography	Tris	tris(hydroxymethyl)-aminomethane
UV	ultraviolet	VFA	volatile fatty acid
vol	volume	vol/vol	volume/volume
vs	versus	wt	weight
wt/vol	weight/volume	wt/wt	weight/weight
x	multiplied by or crossed with		

Sample Number:__________

Baling Contractor:__________________

Field Location:____________________________

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GRASS STRAW SURVEY

Species:____

Variety:____

Swathing Date:____

Seed Harvest Date:____________________________________

Was Vegetation Reclipped?:____________________________

Reclipped Date:_______________________________________

Age of Stand:____

Soil Type:____

Grass Seed Production (amount):_______________________

Grass Straw Production (amount):______________________

Fertilizer Type:______________________________________

Fertilizer Rate:______________________________________

Herbicides/Fungicides/Pesticides:_____________________

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________ **I would like a copy of the test results**