The ability of a yeast-derived cell wall preparation to minimize the toxic effects of high-ergot alkaloid tall fescue straw in beef cattle[1,2]

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ABSTRACT: Two experiments were conducted to evaluate the influence of a yeast-derived cell wall preparation (YCW) on forage intake and digestibility, ruminal fermentation characteristics, serum prolactin and prolactin stores, and milk production in beef cattle consuming high-alkaloid tall fescue straw. In Exp. 1, 16 ruminally cannulated Angus × Hereford steers (200 ± 6 kg of BW) were blocked by BW and within block were assigned to 1 of 4 treatments containing YCW at 0, 20, 40, or 60 g/d. Tall fescue straw (579 μg of ergovaline/kg of DM) was provided at 120% of the previous 5-d average intake, with soybean meal used as a CP supplement. In the 29-d digestion study, total DM, OM, and NDF intakes and DM, OM, and NDF digestibilities were not affected by YCW supplementation ($P > 0.13$). Linear decreases in ruminal indigestible ADF outflow ($P = 0.10$) and liquid dilution rate ($P = 0.03$) were noted as YCW increased. Weekly serum prolactin was not affected by treatment ($P > 0.50$), but prolactin stores increased linearly as YCW increased ($P = 0.05$). In Exp. 2, 60 Angus × Hereford cows (517 ± 5 kg of BW; approximately 200 d of gestation) were stratified by BCS (5.0 ± 0.1) and randomly assigned to the same 4 YCW treatments as in Exp. 1 (447 μg of ergovaline/kg of DM, high-alkaloid straw), but with the addition of a low-alkaloid straw (149 μg of ergovaline/kg of DM; no YCW supplementation) as a control. Cows were provided ad libitum access to straw, and diets were supplemented with soybean meal daily. One cow was removed from the 40 g/d treatment because of clinical signs of fescue foot. No differences ($P > 0.20$) were observed in pre- or postcalving BCS change or postcalving BW change. Control cows gained more BW ($P = 0.02$) precalving compared with cows given 0 g/d of YCW. A linear increase ($P = 0.04$) in milk production at 60 d postpartum was observed as YCW increased. Serum prolactin postcalving and the change from initial to postcalving increased linearly ($P = 0.02$ and $P = 0.06$, respectively) with increasing YCW supplementation. In addition, postcalving serum prolactin was less for 0 g/d of YCW compared with the control ($P = 0.003$) and 20 g/d of YCW ($P = 0.04$). The YCW seemed to alleviate the prolactin depression normally associated with fescue toxicosis and therefore has the potential to be used successfully with other management practices when feeding or grazing high-alkaloid tall fescue.

Key words: cattle, ergot alkaloid, ergovaline, prolactin

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INTRODUCTION

Production of grass seed in the United States is centered in the Pacific Northwest, where more than 180,000 t of tall fescue straw (*Festuca arundinacea*) is produced each year (Young, 2005). Historically, tall fescue straw was burned, but environmental implications and the danger associated with burning necessitated a significant reduction. Currently, the most common use of tall fescue straw is as forage for ruminant livestock (Hovermale and Craig, 2001), but use of some varieties is limited because of the endophyte *Neotyphodium coenophialum* (Morgan-Jones and Gams, 1982)

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and associated ergot alkaloids. This is because tall fescue straw is used primarily as a winter feed source (Bohnert and Merrill, 2006) and, without proper management, intake of ergot alkaloids during this period often results in fescue foot (Hemken et al., 1984; Bohnert and Merrill, 2006).

Ergot alkaloids ingested by ruminants have been reported to decrease feed intake, elevate body temperature, lead to excessive salivation, increase respiration rate, decrease reproductive efficiency, and decrease peripheral circulation; these symptoms are collectively known as fescue toxicosis (Rhodes et al., 1991; Mizinga et al., 1992; Aldrich et al., 1993). Other maladies associated with fescue toxicosis include fescue foot, fat necrosis, and agalactia (Hemken et al., 1984; Paterson et al., 1995). Paterson et al. (1995) reported decreased serum prolactin as a consistent measurable result of fescue toxicosis. Research has suggested that a yeast-derived cell wall preparation (**YCW**) may minimize, or alleviate, negative effects of endophyte toxins on animal performance (Akay et al., 2003a; Ely et al., 2003; Aaron et al., 2006).

Our objectives were to determine the influence of YCW on forage intake and digestibility, ruminal fermentation characteristics, serum prolactin and prolactin stores, incidence of fescue foot, and milk production in beef cattle consuming high-ergot alkaloid tall fescue straw during late fall and winter.

MATERIALS AND METHODS

The experimental protocol was approved by the Institutional Animal Care and Use Committee at Oregon State University.

Exp. 1: Digestion and Physiology Study

Sixteen ruminally cannulated Angus × Hereford steers (200 ± 6 kg of BW) were used in a randomized complete block design in December of 2005. Steers were blocked by BW and, within block, were randomly assigned to treatments and housed in individual pens (2 × 4 m) within an enclosed barn, without temperature control and with continuous lighting. Steers had unrestricted access to fresh water. Before straw feeding (0700), a trace mineralized salt mix (22 g/d; ≥96% NaCl, ≥0.20% Mn, ≥0.10% Fe, ≥0.10% Mg, ≥0.05% S, ≥0.025% Cu, ≥0.01% Co, ≥0.008% Zn, and ≥0.007% I) and soybean meal (**SBM**; 0.068% of BW; CP basis) were supplemented intraruminally via cannula to meet 100% of the estimated degradable intake protein requirement, assuming a microbial efficiency of 11% (NRC, 1996; model 1). A YCW (MTB-100, Alltech Inc., Nicholasville, KY) was provided to yield the following treatments: 1) 0 g/d of YCW (**YCW0**), 2) 20 g/d of YCW (**YCW20**), 3) 40 g/d of YCW (**YCW40**), and 4) 60 g/d of YCW (**YCW60**). The appropriate quantity of YCW was added to each steer's SBM-trace mineralized salt supplement daily. All steers consumed high-ergot alkaloid (579 μg/kg of ergovaline; DM basis) tall fescue straw that had been processed with a bale chopper (BC-900, Newhouse Manufacturing; Redmond, OR) to yield a particle length of 4 to 8 cm. Tall fescue straw was provided at 0730 at 120% of the previous 5-d average intake, with orts from the previous day determined before feeding. Nutrient content of straw and SBM is provided in Table 1.

The experimental period was 29 d, with 19 d of diet adaptation and 10 d of sampling. Intake and orts were monitored throughout the experiment, but official measurements were taken on d 20 through 25 and d 21 through 26 for intake and orts, respectively. Straw and orts samples for alkaloid analysis were air-dried, ground in a Wiley mill (1-mm screen, model 4, Arthur H. Thomas Co., Philadelphia, PA), and stored (–20°C) for later analysis. Additional samples of high-ergot alkaloid straw, SBM, and orts were collected, dried in a forced-air oven (55°C; 48 h), reweighed for calculation of DM, ground in a Wiley mill (1-mm screen), and composited by source for straw and SBM and by steer for orts.

At 0700 on d 21, immediately following supplementation, each steer was intraruminally pulse-dosed with 4 g of Co-EDTA in a 150-mL aqueous solution (Uden et al., 1980) to determine ruminal liquid fill and dilution rate. The Co marker was administered throughout the rumen by using a stainless-steel probe with a perforated tip. Ruminal fluid (approximately 100 mL) was collected by suction strainer (Raun and Burroughs, 1962; 19-mm diameter, 1.6-mm mesh) prior to SBM supplementation and at 3, 6, 9, 12, 18, and 24 h after Co-EDTA dosing. Samples were immediately analyzed for pH, subsampled by placing 5 mL of ruminal fluid in 1 mL of 25% (wt/vol) meta-phosphoric acid, and stored (–20°C) for later analysis of NH_3-N and VFA. In addition, 20 mL of ruminal fluid was stored (–20°C) for later analysis of Co concentration.

Frozen NH_3-N and VFA samples were prepared for analysis by thawing, centrifuging (10,000 × *g*; 20 min), and collecting the supernatant. Volatile fatty acids were analyzed as described by Harmon et al. (1985), and NH_3-N was determined by a modification (sodium salicylate was substituted for phenol) of the procedure described by Broderick and Kang (1980), with a UV-visible light spectrophotometer (UVmini1240, Shimadzu, Columbia, MD). Frozen ruminal fluid samples were prepared for Co analysis by thawing, centrifuging (2,000 × *g*; 20 min), and collecting the supernatant. Cobalt concentration in ruminal fluid was analyzed by atomic absorption by using an air-acetylene flame (model 351 AA/AE spectrophotometer, Instrumentation Laboratory Inc., Lexington, MA). Ruminal fluid fill and dilution rate were determined by regressing the natural logarithm of Co concentration against sampling time, as described by Warner and Stacey (1968).

Spot urine samples were collected at 0700 on d 22 to 27. Urine samples were collected in polyethylene bags (25 × 35 cm) split diagonally and secured with string over the withers and hips of the animal. Bags were left

Table 1. Nutrient content of the feedstuffs (DM basis)

	Exp. 1 (steer study)		Exp. 2 (cow study)		
Item	High-ergot alkaloid tall fescue straw	Soybean meal	High-ergot alkaloid tall fescue straw	Low-ergot alkaloid tall fescue straw	Soybean meal
CP, %	5.8	54.0	5.6	6.5	52.7
OM, %	94	93	92	92	93
NDF, %	69	13	72	71	13
ADF, %	44	5	43	43	5
Ergovaline, μg/kg	579	NA[1]	449	147	NA
Lysergic acid, μg/kg	68	NA	11	<10	NA

[1]NA = not analyzed.

until a sample was collected, which never exceeded 1.5 h. Urine samples were composited by steer and stored (–20°C) for later analysis of creatinine (277-10501, Wako Chemicals US Inc., Richmond, VA) and ergot alkaloids as described by Hovermale and Craig (2001) and Lodge-Ivey et al. (2006). Daily urinary output was calculated based on an estimated excretion rate of 28 mg of creatinine/kg of BW (Whittet et al., 2004).

On d 22 through 27, fecal grab samples were collected 2 times/d at 12-h intervals, with a 2-h increment added between days to shift the sampling times. This allowed sampling on every even hour of the 24-h day. Fecal subsamples (200 g) were composited by steer, stored (–20°C), lyophilized, and ground in a Wiley mill (1-mm screen).

On d 28, treatment effects on ruminal DM and indigestible ADF (**IADF**) fill were determined by manually removing the reticuloruminal contents 4 h after feeding. Total ruminal contents were weighed, thoroughly mixed by hand, and subsampled (300 g/subsample, wet weight) in triplicate. The remaining ruminal contents were replaced immediately in the steer. Ruminal samples were weighed, dried in a forced-air oven (55°C; 96 h), reweighed for DM, ground to pass a 1-mm screen in a Wiley mill, and composited by steer.

Ground samples were analyzed for DM and OM (AOAC, 1990), N (Leco CN-2000, Leco Corp., St. Joseph, MI), and NDF (Robertson and Van Soest, 1981) and ADF (Goering and Van Soest, 1970) by using procedures modified for use in an Ankom 200 fiber analyzer (Ankom Co., Fairport, NY). In addition, samples were analyzed for IADF as described by Bohnert et al. (2002). The digesta kinetic techniques described by Van Soest (1994) were used to determine IADF passage by dividing IADF intake by the quantity of IADF in the rumen at 4 h after feeding. Diet digestibility was determined by using IADF fecal concentration in conjunction with nutrient concentration of forage and SBM (Merchen, 1988). Air-dried straw and orts and lyophilized fecal samples were analyzed for ergovaline and lysergic acid by HPLC, as described by Hovermale and Craig (2001) and Lodge-Ivey et al. (2006), respectively.

Rectal (GLA M500, Agricultural Electronics, San Luis Obisbo, CA) and skin (RayngerST, Raytek, Santa Cruz, CA) temperatures were measured at 1300 on d 1, 8, 15, 22, and 29. Daily ambient temperature was recorded hourly using a weather station (Model 012, Campbell Scientific Inc., Logan, UT), which was located within 300 m of the study location. In addition, 4 h after feeding on d 1, 8, 15, and 22, 10 mL of blood was collected by coccygeal venipuncture into sterile, nonadditive red-topped tubes (Becton Dickinson and Company, Franklin Lakes, NJ) and 20-ga × 2.54-cm blood collection needles (Becton Dickinson and Company, Rutherford, NJ). Blood samples were allowed to clot overnight at 4°C and centrifuged (1,500 × *g*, 20 min, 4°C), and the serum was harvested and stored (–20°C) for prolactin analysis, as described by Hockett et al. (2000).

Thyrotropin-Releasing Hormone Challenge. Steers were subjected to a thyrotropin-releasing hormone (**TRH**) challenge to measure pituitary prolactin stores on d 29. The afternoon prior to the challenge, steers were catheterized via the jugular vein with Radiopaque FEP Teflon i.v. catheters (16 ga × 14 cm; Abbot Hospitals Inc., North Chicago, IL). On the day of the challenge, TRH (no. P2161, Sigma, St. Louis, MO) was reconstituted by using 0.01 *M* acetic acid, and was mixed with sterile physiological saline for a final concentration of 30.36 μg of TRH/mL. Each steer was dosed with 1 μg of TRH/kg of BW via the jugular catheter (fitted with a 0.2-μm, low-protein-binding, nonpyrogenic filter; PN 4612, Pall Life Sciences, East Hills, NY), followed by 20 mL of sterile saline to chase the peptide. Blood samples were collected at –30, –15, 0 (before TRH administration), and 5, 10, 15, 20, 30, 45, 60, 90, 120, and 150 min (post-TRH administration). Catheters were kept clot free between sampling times by flushing with 10 mL of physiological saline. Blood samples were immediately transferred to red-topped Vacutainer tubes and allowed to clot overnight at 4°C. Samples were then centrifuged (1,500 × *g*, 20 min, 4°C) and serum was harvested and stored (–20°C) for prolactin analysis as described previously. The –30-, –15-, and 0-min samples were averaged and used to calculate a basal prolactin concentration (pre-TRH administration; Thompson et al., 1987). Area under the curve was determined for prolactin by using the trapezoidal summation method.

Statistical Analysis. Data were analyzed as a randomized complete block by using PROC GLM (SAS Inst. Inc., Cary NC). Treatment and block were included in the model. Contrast statements were 1) linear effect of increasing YCW, and 2) quadratic effect of increasing YCW. Ruminal pH, NH_3-N, and VFA, and TRH challenge data were analyzed by using the REPEATED statement with PROC MIXED of SAS. The model included steer, treatment, block, hour, and treatment × hour. In addition, weekly temperature and serum prolactin data were analyzed using the REPEATED statement with PROC MIXED of SAS. The model included steer, treatment, block, day, and treatment × day. The same contrasts described above were used to partition treatment effects for ruminal pH, NH_3-N, VFA, temperature, and serum prolactin. An autoregressive covariance structure (AR1 of PROC MIXED of SAS) was determined to be most appropriate based on Akaike's information criterion.

Exp. 2: Cow Performance, Parturition, and Milk Production

Sixty pregnant (approximately 200 d of gestation) Angus × Hereford cows (517 ± 5 kg of BW) were stratified by BCS (5.0 ± 0.1; Herd and Sprott, 1986) and assigned randomly to 1 of 20 pens and 1 of 5 treatments (3 cows/pen; 4 pens/treatment) in a randomized complete block design in January of 2006. All cows had unrestricted access to fresh water and a loose, trace mineralized salt (≥96% NaCl, ≥0.20% Mn, ≥0.10% Fe, ≥0.10% Mg, ≥0.05% S, ≥0.025% Cu, ≥0.01% Co, ≥0.008% Zn, and ≥0.007% I). A high-ergot alkaloid tall fescue straw and a low-ergot alkaloid tall fescue straw (449 and 147 μg/kg, respectively; Table 1) were used in formulating the following treatments: 1) ad libitum access to low-ergot alkaloid straw (control), 2) ad libitum access to high-ergot alkaloid straw (YCW0), 3) ad libitum access to high-ergot alkaloid straw plus 20 g/d of YCW (YCW20), 4) ad libitum access to high-ergot alkaloid straw plus 40 g/d of YCW (YCW40), and 5) ad libitum access to high-ergot alkaloid straw plus 60 g/d of YCW (YCW60). Straw was provided to the cows directly from 3-tie bales (46 × 122 × 61 cm) without further processing. In addition, SBM was provided (1 kg of DM) daily at 0700 to all treatments to meet 100% of the estimated degradable intake protein requirement, assuming a microbial efficiency of 11% (NRC, 1996; model 1). The top-dressed YCW and SBM were provided in a bunk, with approximately 72 cm of bunk space per cow, within each pen. The high-ergot alkaloid straw was used to estimate the degradable protein requirement because of its lower CP concentration. This was to minimize the potential effects caused by differences in forage CP between the low- and high-ergot alkaloid straws (6.5 vs. 5.6%, respectively). The amount of SBM was doubled (2 kg of DM) for all treatments at d 44 of the trial because cow BW and BCS were not being maintained at the previous supplementation level.

Table 2. Locomotion scoring guide[1]

Score	Description	Assessment
1	Normal	Cow stands and walks with a level back. Normal gait.
2	Mildly lame	Cow stands with a level back, but has an arched back when walking. Normal gait.
3	Moderately lame	Arched back while standing and walking. Short-strided gait.
4	Lame	Arched back is very evident. Deliberate gait favoring one or more feet or legs.
5	Severely lame	Cow demonstrates an inability or extreme reluctance to bear weight on one or more feet or legs.

[1]Adapted from Sprecher et al. (1997). Animals with a score of 3 or greater were removed from study.

Straw samples for alkaloid analysis were obtained weekly, stored (–20°C), and analyzed as described in Exp. 1. In addition, additional samples of low- and high-ergot alkaloid straw and SBM were collected weekly, dried in a forced-air oven (55°C; 48 h), reweighed for calculation of DM, ground in a Wiley mill (1-mm screen), and composited by source and period for analysis of NDF, ADF, N, and OM, as described in Exp. 1.

An evaluation of all cows was conducted daily at 0630. Appraisal included assigning a locomotion score from 1 to 5 (adapted from Sprecher et al., 1997; Table 2); a locomotion score of 3 or greater was assumed to be indicative of fescue foot and necessitated removal from the study (1 cow on d 55). Ambient temperature was recorded as described in Exp. 1. The pens used in the current study were located within 200 m of the weather station.

Cow BW and BCS were measured at study initiation (d 1), d 28, and every 14 d thereafter until calving. All BW were obtained after an overnight shrink (16 h). Body condition score of the cows was evaluated independently by 3 trained technicians. The same technicians were used throughout the trial. In addition, cow BW and BCS and calf BW were obtained within 24 h after parturition.

Blood samples (approximately 10 mL) were collected by coccygeal venipuncture into sterile, nonadditive, red-topped tubes (Becton Dickinson and Company) and 20-ga × 2.54-cm blood collection needles (Becton Dickinson and Company) on d 1 and within 24 h after parturition. Blood was allowed to clot overnight. Samples were then centrifuged (1,500 × *g*, 20 min, 4°C) and serum was harvested and stored (–20°C) for prolactin analysis, as described previously (Exp. 1 and 2; interassay CV = 5.0%, and intraassay CV = 8.0%).

After parturition (75 ± 2 d from study initiation), cows and calves were placed in a common pasture (7.3 ha) that had been harvested for hay the previous summer, and the cows and calves were managed as a single group. Cows were provided approximately 11.2 kg/d (DM basis) of meadow hay (6.3% CP, DM basis). One

Table 3. Effect of increasing yeast-derived cell wall preparation (YCW) on daily nutrient intake and diet digestibility of steers consuming high-alkaloid tall fescue straw

	YCW, g/d					*P*-value	
Item	0	20	40	60	SEM[1]	Linear	Quadratic
DMI, g/kg of BW							
Straw	18.6	17.7	17.8	17.2	1.0	0.40	0.86
Soybean meal	1.2	1.2	1.2	1.2	—	—	—
Total	19.8	18.9	19.0	18.5	1.0	0.40	0.86
OM intake, g/kg of BW							
Straw	17.6	16.7	16.8	16.3	0.9	0.39	0.86
Soybean meal	1.16	1.16	1.16	1.16	—	—	—
Total	18.7	17.9	17.9	17.4	0.9	0.39	0.86
N intake, g/kg of BW	0.77	0.77	0.77	0.77	0.01	0.71	0.92
NDF intake, g/kg of BW	13.1	12.5	12.5	12.2	0.7	0.36	0.83
Total-tract apparent digestibility, %							
DM	46.3	47.2	47.1	45.9	0.8	0.73	0.21
OM	50.3	51.8	52.0	50.9	0.8	0.54	0.14
NDF	44.5	46.4	46.7	46.0	0.9	0.27	0.17

[1]n = 4.

week after the last cow calved, cow-calf pairs were moved to the Northern Great Basin Experimental Range 72 km west-southwest of Burns, Oregon. Cow-calf pairs grazed a sagebrush-bunchgrass range, as described by Ganskopp (2001), and were managed according to Northern Great Basin Experimental Range and Eastern Oregon Agricultural Research Center management practices. Postpartum (60 ± 2 d) milk production was estimated using the weigh-suckle-weigh technique (Williams et al., 1979), with an 8-h separation. Excretory losses were considered minimal and were not collected (Lampkin and Lampkin, 1960).

Statistical Analyses. Data were analyzed as a randomized complete block by using PROC GLM (SAS Inst. Inc.). Treatment and block were included in the model. Contrast statements were 1) linear effect of increasing YCW supplementation, 2) quadratic effect of increasing YCW supplementation, 3) control vs. YCW0, and 4) YCW0 vs. YCW20. The fourth contrast was included to evaluate no supplement compared with the maximum currently recommended dose of 20 g/d.

RESULTS AND DISCUSSION

Exp. 1: Digestion and Physiology Study

No animals in this experiment exhibited physical symptoms of fescue toxicosis. Neither straw (17.8 g/kg of BW daily) nor total DMI (19.1 g/kg of BW daily) was affected by YCW supplementation ($P > 0.39$; Table 3). Likewise, straw (16.8 g/kg of BW daily) and total OM (18.0 g/kg of BW daily) intakes were not affected by YCW supplementation ($P > 0.38$; Table 3). In addition, daily N (0.77 g/kg of BW) and NDF (12.6 g/kg of BW) intakes were similar among levels of YCW supplementation ($P > 0.35$). These results are inconsistent with Akay et al. (2003b), who noted increased DMI ($P < 0.05$) in steers fed endophyte-infected tall fescue seed with a YCW supplement compared with those without (8.46 vs. 7.81 kg/d). However, Akay et al. (2003b) kept steers at an ambient temperature of 30°C, compared with the low ambient temperature in the current study (daily average: –2°C; daily average minimum: –9°C: daily average maximum: 5°C). Hemken et al. (1981) suggested that DMI of cattle consuming endophyte-free or endophyte-infected tall fescue did not differ in an environment of 23°C or less. Consequently, heat stress may have decreased intake of endophyte-infected tall fescue forage in the study by Akay et al. (2003b). Our observation that YCW did not affect ($P > 0.13$) total tract DM, OM, or NDF digestibility (Table 3) agrees with other research evaluating the effect of supplemental yeast culture on nutrient digestibility in ruminants (Mir and Mir, 1994; Kawas et al., 2007).

Means for ruminal fermentation characteristics were averaged across time because no treatment × hour interactions occurred ($P > 0.17$). Increasing supplementation of YCW did not affect ($P > 0.10$) ruminal NH_3-N, pH, or total VFA (Table 4). Molar proportions of propionate, isobutyrate, butyrate, isovalerate, and valerate were not affected by increasing YCW. However, molar percent of acetate ($P = 0.08$) and acetate:propionate ratio ($P = 0.09$) did exhibit a quadratic tendency, with the greatest value observed for YCW20. We are aware of no data evaluating ruminal fermentation variables in response to increasing YCW with forage-based diets.

No differences ($P > 0.49$) were detected in liquid volume, although dilution rate decreased linearly ($P = 0.03$) with increasing YCW (Table 4). In addition, IADF outflow tended ($P = 0.10$) to decrease with increasing YCW supplementation. However, this decrease is probably not biologically important, because we noted no differences ($P > 0.25$) in IADF intake or ruminal IADF fill and passage rate. Other research has suggested that increasing intake of ergot alkaloids decreases ruminal

Table 4. Effect of increasing yeast-derived cell wall preparation (YCW) on ruminal fermentation and fluid and particulate dynamics in steers consuming high-alkaloid tall fescue straw

	YCW, g/d					*P*-value	
Item	0	20	40	60	SEM[1]	Linear	Quadratic
NH_3-N, m*M*	4.2	5.8	4.3	4.5	0.4	0.78	0.18
pH	6.7	6.6	6.8	6.6	0.1	0.69	0.71
Total VFA, m*M*	79.9	79.7	85.1	78.7	3.7	0.92	0.42
VFA, mol/100 mol							
Acetate	67.0	70.3	68.0	69.0	0.6	0.21	0.08
Propionate	22.1	19.8	21.6	20.9	0.5	0.39	0.13
Isobutyrate	0.7	0.7	0.7	0.7	0.1	0.66	0.99
Butyrate	8.3	7.6	8.1	8.0	0.2	0.79	0.90
Isovalerate	0.9	0.9	0.8	0.8	0.1	0.54	0.80
Valerate	0.9	0.7	0.8	0.8	0.1	0.35	0.34
Acetate:propionate ratio	3.1	3.6	3.2	3.3	0.1	0.40	0.09
Liquid volume, mL/kg of BW	60.4	68.7	62.0	66.7	4.0	0.50	0.65
Liquid dilution rate, %/h	7.8	6.1	7.0	6.2	0.2	0.03	0.22
Indigestible ADF intake, g/kg of BW	5.3	5.0	5.0	4.9	0.3	0.60	0.47
Indigestible ADF fill, g/kg of BW	13.1	14.2	12.1	14.4	0.8	0.60	0.47
Indigestible ADF passage, %/h	10.2	9.0	10.5	8.5	0.7	0.26	0.58
Indigestible ADF outflow, g/h	265	265	251	239	11	0.10	0.62

[1]n = 4.

IADF outflow and passage rate (Stamm et al., 1994; Fisher et al., 2004).

No treatment × day interactions were detected ($P > 0.10$), so means were averaged across days for rectal, flank, and coronary band temperature. Increasing YCW did not influence rectal or flank temperature ($P > 0.17$), although a quadratic response ($P = 0.06$) tended to be observed in coronary band temperature, with YCW40 being the highest (Table 5). Rectal temperatures in animals consuming high-endophyte tall fescue have been shown to increase in heat-stressed environments but, as in the current study, no differences are seen in moderate to colder ambient temperatures (below 27°C; Hannah et al., 1990; Rhodes et al., 1991; Peters et al., 1992). This is the first data of which we are aware evaluating the effect of YCW on coronary band temperature. We anticipated that with the cold environment of the current study, coronary band temperature would increase with increasing YCW, theoretically because of decreased vasoconstriction and improved blood supply resulting from a decrease in ergot alkaloid metabolism (Oliver et al., 1993). It is not clear why we observed the quadratic effect in coronary band temperature, but it is possible that our ability to detect potential treatment differences was influenced by the daily variation in fecal and urine contamination of the hair at the coronary band, which may not have allowed for an accurate measurement of temperature.

Analysis of weekly serum prolactin concentration resulted in no treatment × day interactions ($P > 0.50$), so means were averaged across days. Increasing levels of YCW had no effect ($P > 0.10$) on weekly serum prolactin (Table 5). Prolactin concentrations in Exp. 1 were less than those normally reported in the literature for beef cattle. This may be attributed to the cold ambient temperature and the short daily photoperiod that occurs during winter, causing a decrease in prolactin concentration (Smith et al., 1977; Peters and Tucker, 1978). In addition, Goetsch et al. (1987) reported that consumption of high levels of endophyte-infected tall fescue

Table 5. Effect of increasing yeast-derived cell wall preparation (YCW) on serum prolactin and physiological variables in steers consuming high-alkaloid tall fescue straw

	YCW, g/d					*P*-value	
Item	0	20	40	60	SEM[1]	Linear	Quadratic
Temperature, °C							
Rectal	38.4	38.6	38.6	38.6	0.1	0.40	0.51
Flank	20.4	21.2	21.5	20.1	0.8	0.90	0.18
Coronary band	8.8	8.8	9.8	8.1	0.4	0.55	0.06
Serum prolactin							
Weekly, ng/mL	1.6	2.3	1.7	2.0	0.3	0.63	0.51
TRH challenge AUC, ng	210	343	284	330	32	0.05	0.16

[1]n = 4, except for area under the curve (AUC), where n = 3 for YCW at 0 g/d; the largest SEM is presented.

Table 6. Effect of increasing yeast-derived cell wall preparation (YCW) on daily excretion of ergovaline and lysergic acid in steers consuming high-alkaloid tall fescue straw

	YCW, g/d					*P*-value	
Item	0	20	40	60	SEM[1]	Linear	Quadratic
Diet, μg/kg of BW							
Ergovaline	10.81	10.22	10.17	9.88	0.54	0.26	0.78
Lysergic acid	1.29	1.27	1.23	1.21	0.07	0.35	0.98
Ergovaline + lysergic acid	12.10	11.49	11.40	11.09	0.60	0.27	0.81
Feces, μg/kg of BW							
Ergovaline	5.98	5.88	5.47	5.46	0.38	0.28	0.91
Lysergic acid	1.30	1.25	1.15	1.13	0.07	0.09	0.82
Ergovaline + lysergic acid	7.29	7.13	6.63	6.60	0.42	0.21	0.88
Urine, μg/kg of BW							
Ergovaline	ND[2]	ND	ND	ND			
Lysergic acid	1.32	1.27	1.64	1.26	0.14	0.75	0.24
Urine + feces, μg/kg of BW							
Ergovaline	5.98	5.88	5.47	5.46	0.38	0.28	0.91
Lysergic acid	2.62	2.52	2.80	2.39	0.16	0.57	0.35
Ergovaline + lysergic acid	8.60	8.40	8.27	7.85	0.50	0.32	0.83

[1]n = 4.
[2]ND = not detected.

hay (>50% of the diet) reduced serum prolactin to less than 1.0 ng/mL in steers, which is similar to our overall average (1.9 ng/mL). A longer experimental period may have yielded treatment differences in weekly serum prolactin in the current study because, in the short term, pituitary prolactin stores may have been able to support circulating prolactin levels in the bloodstream. This is supported by the TRH challenge data.

During the TRH challenge, data from 1 steer on YCW0 was excluded because of loss of catheter patency. Prolactin area under the curve for the TRH challenge increased linearly ($P = 0.05$) with increasing YCW (Table 5), but the primary source of the linear effect was the increase in prolactin between the 0 and 20 g/d dose, with little difference between YCW20, YCW40, and YCW60. In contrast to our results, Stamm et al. (1994) reported no difference in serum prolactin in response to a TRH challenge by steers consuming increasing ergovaline levels, but they did not measure the area under the curve and only reported concentration differences. In addition, Stamm et al. (1994) used tall fescue straw with a lower concentration of ergovaline (475 μg/kg) than in our study (579 μg/kg). Nevertheless, other research has noted a depression in TRH-induced prolactin levels across temperature ranges and seasons in ruminants grazing high-endophyte fescue (Hurley et al., 1980; Thompson et al., 1987). Therefore, our results suggest that YCW may be able to correct the prolactin depression normally associated with fescue toxicosis.

No differences ($P > 0.25$) were detected in intake of ergovaline, lysergic acid, or the combination of ergovaline and lysergic acid (Table 6). Lysergic acid was included in the analyses because it results from the degradation of ergot alkaloids containing the core ring structure of lysergic acid, such as ergovaline, ergocryptine, ergotamine, and ergonovine, and recent research has suggested it may be a primary toxin in fescue toxicosis (Hill et al., 2003; De Lorme et al., 2007). No differences ($P > 0.20$) were detected in ergovaline or the combined ergovaline and lysergic acid content of feces. However, fecal content of lysergic acid tended to decrease linearly ($P = 0.09$) as YCW increased, which may be a function of the numerical reduction in ergot alkaloid intake. No differences ($P > 0.23$) were detected in urine lysergic acid content or total excretion (urine and feces) of ergovaline, lysergic acid, or the combination of ergovaline and lysergic acid. Unlike for ergovaline, urine is the primary route of excretion for lysergic acid.

Research conducted by Schultz et al. (2006) and De Lorme et al. (2007) compared fecal and urinary excretion of ergovaline and lysergic acid in horses and sheep consuming ergot alkaloids from tall fescue. Schultz et al. (2006) reported recovery of lysergic acid to be greater than 200% in the urine and 134% in the feces of mature geldings, whereas De Lorme et al. (2007) noted recoveries of 140% in the urine and 113% in the feces of wethers. Our data compare favorably with that of De Lorme et al. (2007), with excretion of lysergic acid in the urine and feces averaging 107 and 96% of intake, respectively, when averaged across all treatments.

It is possible that we may have underestimated urinary excretion of lysergic acid. This is because we collected spot urine samples daily at 0700. In a recent study, Pearce and Masters (2006) measured Na excretion in spot samples of urine from wethers by using the creatinine ratio, as we did in the current study. They noted significant diurnal variation in estimated Na excretion depending on the time of spot sample collection. Consequently, by not collecting spot samples throughout the day, we may not have accurately characterized lysergic acid excretion. In addition, based on data from De Lorme et al. (2007), the concentration of lysergic acid in ruminal fluid appears to increase until approximately 6 h postfeeding and can be maintained for at

least 12 h postfeeding in ruminants consuming endophyte-infected tall fescue. Therefore, given that the rumen is assumed to be the primary site of lysergic acid absorption (Westendorf et al., 1992; Hill et al., 2001) and that we provided straw once daily at 0700, we may not have obtained spot urine samples when lysergic acid excretion was greatest, thereby underestimating excretion. However, all treatments were handled the same, and we do not anticipate that our sampling procedure influenced overall interpretation of the data.

Exp. 2: Cow Performance and Production Study

The daily average ambient temperature from study initiation through parturition (approximately 75 d) was 0°C, with the daily average minimum and maximum being –5 and 6°C, respectively. During the course of the experiment, one cow receiving YCW40 was removed on d 55 because of a lameness score of 4 resulting from fescue foot. This animal made a full recovery, calved without difficulty, weaned a healthy calf, and rebred within a 45-d breeding season. In addition, another cow receiving YCW40 was removed because of misdiagnosis of pregnancy at study initiation. Data from these animals were completely removed from the data set.

Intake of straw was not measured in the current study, but we did note the quantity of straw offered from study initiation to calving. There were no treatment differences in the quantity of straw DM offered ($P > 0.05$), with the control, YCW0, YCW20, YCW40, and YCW60 receiving 13.0, 12.0, 11.9, 12.9, and 11.4 kg/d, respectively (data not shown).

Contrary to Akay et al. (2003a), who reported an increase in BW of cows supplemented with YCW at 20 g/d compared with those not supplemented during a 5-mo period (May to October) when grazing tall fescue, we noted no differences ($P > 0.20$) in pre- or postcalving changes in BW or BCS as YCW increased (Table 7). These differing results may be a function of heat stress in the Akay study compared with the winter temperatures associated with the current experiment. Nevertheless, the precalving BW change increased ($P = 0.02$) in control cows compared with YCW0 cows. In agreement, Paterson et al. (1995) reported lower ADG by cows grazing endophyte-infected fescue compared with cows grazing non-endophyte-infected fescue. Our observed increase in precalving BW change for control cows compared with YCW0 cows may be related to the lower CP content of the high-alkaloid straw, even though we attempted to compensate for the CP difference.

Calf birth weight did not differ ($P > 0.24$) among treatments (Table 7). We did note a quadratic effect ($P = 0.03$) of days from study initiation to calving, with YCW40 being the lowest. This is probably attributed to animal variability and not YCW supplementation.

Suppression of the periparturient surge of prolactin has been reported in cattle consuming ergot alkaloids and is associated with decreased metabolic activity of the mammary cells (Tucker, 1985). In addition, suppressed or reduced prolactin concentrations have been reported in numerous studies with animals consuming high-endophyte diets compared with those consuming low- or no-endophyte diets (Schillo et al., 1988; Stamm et al., 1994; Samford-Grigsby et al., 1997). In this study, postcalving prolactin concentration as well as the change from initial to postcalving serum prolactin concentration increased linearly ($P = 0.02$ and $P = 0.06$, respectively) with increasing YCW (Table 7). This coincides with the linear increase detected with the TRH-challenge area under the curve data in Exp. 1. In addition, postcalving serum prolactin was 112 ng/mL for YCW20 compared with 62 ng/mL for YCW0 ($P = 0.04$), and the change from initial to postcalving prolactin tended ($P = 0.08$) to be greater with YCW20 compared with YCW0. These data, along with the similar postcalving prolactin concentrations for YCW20, YCW40 and YCW60 (112, 100, and 127 ng/mL, respectively), suggest that YCW20 was sufficient to alleviate the prolactin depression observed with intake of high-ergot alkaloid tall fescue straw. In addition, postcalving serum prolactin and the change from initial to postcalving serum prolactin decreased ($P = 0.003$ and $P = 0.004$, respectively) with YCW0 compared with the control.

We are aware of no data evaluating the effects of increasing YCW supplementation on milk production in ruminants consuming high-alkaloid forage. However, Peters et al. (1992) reported that daily milk production was 25% lower in animals consuming endophyte-infected compared with endophyte-free tall fescue. In our study, milk production of cows that consumed high-ergot alkaloid tall fescue straw during the last third of gestation increased linearly ($P = 0.04$) as YCW increased (Table 7). Despite differences in milk production, calf BW at the time of weigh-suckle-weigh was not affected ($P > 0.13$) by treatment (86, 86, 84, 83, and 95 kg for control, YCW0, YCW20, YCW40, and YCW60, respectively; data not shown). In addition, calf BW gain from birth to weigh-suckle-weigh was not influenced by treatment ($P > 0.12$) and averaged 0.83 kg/d across all treatments (data not shown). Nevertheless, the YCW-related increase in milk production was similar to the observed increase in cow serum prolactin concentration.

Increasing YCW resulted in greater prolactin stores, alleviated prolactin depression, and increased milk production of beef cattle consuming high-ergot alkaloid tall fescue. Based on our data and other research (Akay et al., 2003a,b; Aaron et al., 2006), 20 g/d of YCW normally appears to be sufficient to reduce the consequences of fescue toxicosis (principally decreased performance and serum prolactin) normally observed with intake of endophyte-infected tall fescue by beef cattle. The mode of action for YCW is not clear, but it has been proposed that YCW binds the toxin(s) causing fescue toxicosis (Akay et al., 2003a). Nevertheless, ergovaline and lysergic acid excretion in the current study were not influenced by increasing YCW. It is possible that metabolism

Table 7. Effect of increasing yeast-derived cell wall preparation (YCW) on performance and serum prolactin in cows consuming high- or low-alkaloid tall fescue straw

		YCW,[2] g/d					*P*-value			
Item	Control[1]	0	20	40	60	SEM[3]	Linear	Quadratic	Control vs. 0	0 vs. 20
Initial										
BW,[4] kg	529	522	514	511	515	10	0.60	0.60	0.62	0.61
BCS	5.0	5.0	5.0	5.0	5.0	0.1	0.82	0.31	0.89	0.46
Precalving change[5]										
BW,[4] kg	44.0	21.8	30.1	22.0	26.2	6.1	0.85	0.73	0.02	0.35
BCS	0.07	0.04	0.08	-0.03	0.08	0.09	0.95	0.66	0.81	0.78
Postcalving change[6]										
BW,[4] kg	–1.2	–15.3	–7.7	–5.0	–17.7	6.4	0.87	0.14	0.15	0.42
BCS	–0.08	–0.05	–0.03	0.02	–0.06	0.13	0.99	0.82	0.84	0.91
Days to calving[7]	73.2	77.0	70.8	68.2	82.8	4.2	0.45	0.03	0.54	0.32
Calf birth weight, kg	36.8	37.2	37.2	35.2	38.5	1.5	0.80	0.31	0.82	0.99
Serum prolactin, ng/mL										
Initial	27	41	38	43	39	13	0.99	0.96	0.47	0.88
Postcalving[6]	146	62	112	100	127	16	0.02	0.49	0.003	0.04
Postcalving – initial	119	22	74	57	88	19	0.06	0.59	0.004	0.08
Milk production,[8] kg	12.5	9.8	11.2	13.6	14.2	1.4	0.04	0.79	0.21	0.52

[1]Control = cows receiving no YCW + ad libitum access to low-alkaloid tall fescue straw (147 μg/kg of ergovaline).
[2]Cows with ad libitum access to high-alkaloid tall fescue straw (449 μg/kg of ergovaline).
[3]n = 4.
[4]After a 16-h withholding of food and water.
[5]From study initiation to within 14 d precalving.
[6]From study initiation to within 24 h after parturition.
[7]From study initiation.
[8]60 ± 2 d after parturition.

or excretion of an alkaloid(s) not measured could have been influenced by YCW supplementation and caused the observed effects. Further research is warranted concerning the mechanism by which the YCW reduces the effects of fescue toxicosis.

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