Videothermometry for Assay of Fescue Foot in Cattle

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SUMMARY

Surface temperatures of hoofs of calves given toxic anion fractions of tall fescue were measured with an infrared sensitive camera. These changes expressed in terms of a weighted average coronary band temperature relate to clinical signs of fescue foot. The weighted average coronary band temperature values for control calves given saline solution were 27 to 31 °C; those values of test calves given anion fractions of tall fescue were as low as 22 ± 1 °C. Videothermometry provides an independent, permanent, objective measure that is useful in assessing fescue-foot potential of tall fescue fractions by intraperitoneal injection. Videothermometry may also serve as a clinical means for determining progression of the total fescue foot syndrome.

Tall fescue (Festuca arundinacea Schreb) is used extensively as a cool season pasture forage for beef cattle and comprises 18.7 million acres of an estimated 63.3 million acres of grassland in the southeastern United States (Missouri southward and eastward, excluding Florida). Total acreage of this grass has increased during the past 30 years, even though it is associated with several cattle diseases (fescue foot, lipomatosis summer slump). This increase illustrates the need for a cool season forage. Calves injected intraperitoneally (IP) with crude ethanolic and anion fractions of toxic tall fescue showed lameness, swelling, and reddening of the hindlimb coronary bands, discoloration of the tip of the tail, and other clinical signs of fescue foot. These clinical signs, occurring mainly in the pelvic limbs, are accompanied or preceded by changes in the temperature of the affected limb.

Videothermometry adds a new dimension to the IP cattle assay, allowing us to monitor daily temperature changes in cattle, thereby determining the biological potency of fractions. As described in a publication by the manufacturer (No. 556174), thermal data on each calf are recorded by means of an infrared sensing camera system. Infrared radiations emitted by the foot surface are converted to electrical signals by the camera detector; these signals, in turn, control the electron beams of television-type picture tubes and produce a visual image of the calf's foot as a composite of isotherms (Fig 1). The absolute temperature of any portion of the foot can be determined by comparison to a temperature reference standard. The weighted average coronary band temperature (WACBT) of a calf showing clinical signs of fescue foot differs significantly from that of normal calves. Further use of videothermometry may reveal additional pertinent knowledge of the pharmacodynamics of fescue foot.

The purpose in the present report was to determine the cause of tall fescue's undesirable traits and to give plant breeders the information needed to select nontoxic varieties of tall fescue.

Materials and Methods

Extraction of Toxic Hay—Fall regrowth of toxic tall fescue was harvested in December, and was dried. This hay was extracted by covering the residue with 80% aqueous ethanol. This mixture was stirred approximately 24 hours and then the first extract was removed; a second extract was prepared similarly. The combined extracts were diluted with distilled water to 55% ethanol. Cation exchange resin (H+) was added to the extract periodically, decreasing the pH to approximately 2.5. After stirring overnight, the mixture was filtered to remove the resin, waxes, and other lipoidal components. The clear, acidic solution was passed through columns of anion exchange resin (OH-). These columns were washed with a small amount of 55% ethanol and then with water until repeated Molisch's tests were consistently faint in color. The resin was drained and extruded, and the upper yellow portion ("top anions") was separated from the black portion ("bottom anions"). The black "bottom anion" resin was eluted with formic acid.

6N Formic Acid Eluates—Resin containing anions from either Kenhy or Ky-31 tall fescue was mixed with 6 N formic acid to displace uncharged hydroxide ions and to exchange all carbonate ions. A column formed from the slurry was eluted with 6 N formic acid (tenfold calculated resin capacity equivalents). The formic acid eluate was concentrated, lyophilized to remove water and formic acid, then reconstituted with distilled water. The pH was adjusted with NaOH, to 7.4 and the solution was sterilized by filtering through a 0.22-μm filter. Portions of this solution containing anticipated daily doses were added to sterile IV infusion bottles and diluted to 1 L with isotonic saline solution or deionized water. If possible, doses were diluted to be isotonic.

1N Formic Acid Eluate—Resin contain-
Fig 1—Diagram of videothermometry record of control (left) and test (right) calf's foot.

WACBT value of left diagram is 29°C;
WACBT value of right diagram is 23°C.

Intraperitoneal Administration of Eluates—The IP administration was essentially that described by Williams et al. Test solutions or an isotonic saline solution (control) were administered daily to Hereford calves weighing 160 to 230 kg for 12 to 14 days. The doses, expressed as a value equivalent to a quantity of hay, were increased stepwise during the assay. Occasionally, the dose was altered to keep calves on feed. The ration consisted of brome grass hay and alfalfa waters.

Videothermometry—Surface temperature data were collected with an infrared camera system (Thermovision Model 680°), a color monitor (Model 700°), a Textronic oscilloscope camera, temperature reference standard (Model 23°). These instruments are of sturdy design, are easily assembled and disassembled, and function correctly at near freezing temperatures. The camera was mounted on a short dolly so that the lens (protected with one thickness of plastic film) was about 46 cm above the floor. Calves were made to stand in a specially designed chute that positioned their hoofs in line with, and perpendicular to, the camera axis. The camera was focused on the outside digit of each foot (pelvic limb) and the visual image of heat contours in the lower limb and foot was recorded on color film. Pertinent data such as calf number, date, and color of isotherm representing 28°C were recorded on the back of each color print. The sensitivity of the camera system was set so that each of ten colors recorded represented a two-degree (C) change (Fig 1).

The WACBT was calculated by adding the temperature at 1-mm intervals along an imaginary line across the picture of the foot at the coronary band, and then dividing the sum by the number of readings taken. A WACBT value was calculated for the outside digit of each foot (pelvic limb) on each calf each day for 12 to 14 days.

Results

The WACBT values vs day of experiment for calves given toxic anion fractions differ from those of calves given the isotonic saline solution (Fig 2). As the experiment progressed, test calf 7041 given toxic anions from Mo-96...
tall fescue (February 1978) showed a general decrease in WACBT values in both hooves while calf 7034 given the isotonic saline solution showed a general increase in WACBT values. There were some similarities in the data of test and control calves. Variations between left and right feet of each calf were slight; daily variations within each graph were pronounced.

Records of videothermometry data were available for three IP cattle assays: January 1976, February 1977, February 1978. These data (Table 1) were average WACBT values of days 2 through 12.

The WACBT values for a control calf given isotonic saline solution were approximately 27 in 1977 and again in 1978. Although the WACBT values for a test calf given a toxic anion fraction were lower; the amount of difference depended on the relative toxicity of the fraction. In 1977 and 1978, WACBT values of test calves frequently reached 22 ± 1 C. A review of the clinical signs summarized in Table 1 indicates that WACBT values generally correlate with the toxicity of anion extracts; ie, animals exhibiting the

The +, ++, and +++ refer to severity of clinical signs.

* The average WACBT value for day 2 through 12. The least significant difference (5% level) for comparing treatments tested the same year is 2.0. † See Williams et al.
Discussion

Nelson and Osheim used videothermometry to detect soring in Tennessee Walking Horses. They reported differences in thermograms of a horse with normal proximal interphalangeal joint (pastern joint) and a horse with "sore" pastern. They did not measure absolute temperatures of horses' hoofs, but did examine the physical pattern of the isotherms and the relative differences of isotherms. In contrast, monitoring of the IP cattle assay (present study) showed that normal (control) calves and test calves with clinical signs of fescue foot have similar isotherm patterns. However, the isotherms in thermograms of the hoofs of test calves represented cooler temperatures than those in the thermograms of control calves (Fig 1).

The most useful means of representing these differences was by the WACBT value. After recording the thermal data on film, the color of the temperature reference was noted. The absolute temperature of one color on the picture allowed the calculation of the absolute temperature of each color isotherm. Selection of the region of the coronary band has physiologic significance because of blood vessel arrangement in the area, and because early signs of fescue foot are observed here.

Graphs of WACBT values vs day of experiment exhibit an irregular pattern (Fig 2 and 3), although effort was made to assess and control variability in data collection. This effect may have occurred because each thermogram represented only a few seconds in a given day, and there may have been variations in the effects of ambient temperature or fluctuations during the day in the physiologic response to the fescue foot factor. To date, more frequent monitoring has not been attempted.

Several temperature extremes were experienced during the 1977 cattle assay. Following day 10, the ambient temperature increased from 9 to 17°C. This increase was associated with an increase in rectal temperatures in 50% of the calves tested and higher WACBT values for all calves (Fig 3). In the control calves, only a modest increase was recorded. The increased ambient temperature diminished WACBT differences between control and test calves, which affirms the importance of low temperature in the production of fescue foot. In the present study, the transition from obvious temperature sensitivity to apparent insensitivity occurred near 13°C. Whether there is a precise relationship between temperature and susceptibility to fescue foot remains to be determined. Field observations, however, indicate such a relationship does exist.

Increased WACBT values following an initial decline, as observed in the severely affected calves in February 1977, was unexpected (Fig 3). This effect could be due to inflammation. Tookey et al expressed the hypothesis that erythema and edema precede gangrene; such a succession might also cause an eventual WACBT value increase. In support of this hypothesis, a steer exhibiting severe signs of fescue foot from grazing a toxic Ky-31 pasture had a WACBT value of 35. If data could have been collected until onset of gangrene, WACBT values in affected calves would be expected to drop toward ambient temperature.

An analysis of variance shows that there are few significant differences between left and right foot WACBT values (Fig 2). With the present experimental design (2 calves, 11 days, 2 hoofs/animal), the least significant differences (5% level) for comparing treatments tested the same year is 2.0. Therefore, in future studies, only one

Figure 3—Average daily WACBT values for control and test calves for 1977 IP cattle assay.

In 1976, when WACBT values were relatively high, differences of 1 to 6 degrees (C) were observed between control and test calves. Procedural details were established in that year, using extracts that were mildly toxic (Table 1); persistent clinical signs were not produced in test calves. High WACBT values for calves in 1976 may have been due to one or more of the following: a higher ambient temperature, an unperfected means of measuring absolute temperature, or difference in camera units.

In contrast, 1977 test calves had lasting clinical signs of fescue foot, such as lameness, swelling of the feet, red lines at the coronary bands, and necrotic tail tips. This was the only year in which an analysis of variance showed a significant variation (P < 0.01) in the relation of treatment to day of assay. A graph of WACBT values vs day (Fig 3) shows the temperature patterns for severely and mildly affected test calves.

In 1978 test calves showed less severe clinical signs of fescue foot than in the previous year, with the exception of red lines at the coronary bands. Calves given anions from Mo-96 tall fescue showed the most pronounced red lines and had the lowest WACBT values.

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foot need be monitored. This will simplify the procedure by (i) reducing the number of photographs needed, (ii) allowing the camera to be kept essentially stationary, (iii) allowing the temperature reference source to be placed within the camera’s field of view, and (iv) reducing the limits of temperature range from 20 to 10 °C, making each color isotherm equal to a change of 1 degree (°C). The improved sensitivity which such changes might produce is desirable in assessing relative toxicities if forage supplies of new cultivars of tall fescue are limited, or if further fractionation of the toxic tall fescue anions leads to reduced potency.

References


