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Examination of potential methods to predict pulmonary arterial pressure score in yearling beef cattle[1]

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ABSTRACT: Susceptibility of beef cattle to high altitude disease (HAD) is of major importance to economic and genetic selection on high elevation ranches. However, currently the best indicator of HAD susceptibility is the pulmonary arterial pressure (PAP) test, a test with high cost and invasive nature. Therefore, 2 experiments were undertaken to determine whether emerging technologies that predict blood components could be used to predict the PAP score in yearling Angus cattle. In Exp. 1, 39 yearling Angus bulls were used to determine if a relationship existed between PAP score and 10 blood components provided by a hemogram using whole blood or oxygen saturation as predicted by pulse oximetry in nonanesthetized cattle measured rectally or orally. Three of the hemogram values (packed cell volume, hemoglobin concentration, and red cell distribution width) were correlated ($P < 0.10$) with the PAP score. Prediction equations for PAP score were generated using the hemogram values and resulted in R^2 values of 0.375 and 0.305 for the regression model using all of values and the best 2-variable model, respectively. Pulse oximetry was able to provide oxygen saturation predictions rectally or orally; however, the predicted values were not correlated with the PAP score ($P > 0.10$) or with each other ($P > 0.10$). In Exp. 2, 84 yearling Angus cattle (62 bulls, 22 heifers) were used to evaluate the ability of a portable clinical analyzer to predict the PAP score using 11 blood components from a sample of whole blood evaluated at the processing chute. The portable clinical analyzer was able to provide values for all of the 11 blood components; however, none of the predicted values were correlated with the PAP score ($P > 0.10$). In these preliminary experiments, 3 blood component values provided via the hemogram were the only variables both correlated with the PAP score and able to contribute to the development of a useful PAP prediction equation that could reduce the cost of traditional measures of HAD susceptibility. Future research is needed to determine whether additional blood components or emerging blood analysis technologies are able to accurately predict the PAP score in beef cattle.

Key words: beef cattle, brisket disease, pulmonary arterial pressure

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INTRODUCTION

High altitude disease (**HAD**), commonly called brisket disease, was first described in beef cattle (Glover and Newsome, 1914). Jensen et al. (1976) indicated that HAD was one of the primary causes of calf morbidity and mortality on western beef cattle ranches above 2,133 m. The cumulative annual disease incidence rate for HAD was 0.43 per 100 cows based on data from 39 cow-calf herds in Colorado (Salman et al., 1990).

In cattle, hypoxia at high elevation causes pulmonary vasoconstriction, increased pulmonary arterial pressure (**PAP**), right ventricle stress, congestive right heart failure, and hydrothorax in the chest cavity and brisket (Alexander and Jensen, 1959, 1963). No consistently effective treatment or prevention is available other than movement of affected cattle to lower elevation or selection using an indicator trait.

The indicator trait for HAD, the PAP test, has been shown to be moderately (Schimmel, 1981) to highly (LeValley, 1978; Enns et al., 1992) heritable. The PAP test is a chute-side right heart catheterization procedure performed to measure the average PAP. Typically, cattle with PAP values >45 mmHg are culled, resulting in a reduced incidence of HAD in current and subsequent generations (T. Holt, unpublished data).

Although the PAP test is an effective method to select against HAD susceptibility, few seedstock cattle are

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tested because of the test's invasive, dangerous, and expensive nature. Availability of an easier, cheaper, and less invasive alternative would encourage more testing and allow for the development of a genetic evaluation for susceptibility to HAD.

Early clinical research suggests that the disease process includes changes to blood parameters (Cueva, 1967; Weir et al., 1974) in addition to vasoconstriction. Therefore, the objective of this experiment was to evaluate the relationship between blood components predicted by 3 new blood evaluation technologies (hemogram, pulse oximetry, and portable clinical analyzer) and PAP score.

MATERIALS AND METHODS

Before the initiation of these experiments, all care, handling, and sampling of the animals were approved by the Colorado State University Animal Care and Use Committee.

Exp. 1

Experimental Design. In the first experiment, 39 purebred yearling Angus bulls born and raised at an elevation of 2,200 m (John E. Rouse Colorado State University Beef Improvement Center, Saratoga, WY) were used in early January to collect the following information: PAP score (mmHg), 10 blood components determined by a hemogram using whole blood [1) packed cell volume (**PCV**), 2) hemoglobin concentration (**HgB**), 3) red blood cell (**RBC**) count, 4) mean cell volume (**MCV**), 5) mean cell hemoglobin concentration (**MCHC**), 6) red cell distribution width (**RDW**), 7) nucleated cells, 8) platelet count, 9) mean corpuscular hemoglobin, and 10) mean platelet volume], and arterial oxygen saturation (**SpO_2**) as predicted by pulse oximetry at 2 anatomical locations. A state-licensed veterinarian collected a PAP score on each bull while it was restrained in a hydraulic squeeze chute. A rope halter was used to safely restrain each animal's head during PAP testing (procedure outlined subsequently) and blood collection.

PAP Test. The PAP test is a right heart catheterization procedure requiring jugular venipuncture, catheter insertion, and passage of the catheter through the right atrium and ventricle to the pulmonary artery. Once the catheter is inside the pulmonary artery, an average blood pressure (average of systolic and diastolic values) is recorded from the heart monitor, which is attached to the catheter via a transducer. A small number of experienced veterinarians in the Rocky Mountain States perform the PAP test as a service to clients raising beef cattle at high elevation. In Exp. 1, 11 of the 39 bulls evaluated had elevated (>45 mmHg) PAP scores.

Hemogram. The 10 hemogram values specified previously were determined from venous blood collected into nonheparinized Vacutainer tubes (Becton Dickinson Co., Franklin Lakes, NJ) immediately after collection of the PAP score and removal of the catheter. Once collected, the samples were placed on ice for 3 h before being transported to the laboratory for hemogram analysis (Colorado State University Veterinary Teaching Hospital Blood Analysis Laboratory, Fort Collins). A hemogram was completed on all samples within 6 h from the time of collection.

Pulse Oximetry. A pulse oximeter with a corresponding reflectance probe (Heska Vet/Ox 4404, Heska Corp., Fort Collins, CO) was used to collect chute-side SpO_2 values. A transmittance probe is typically applied to an easily accessible portion of an animal that is well vascularized (e.g., tongue) to monitor SpO_2 while the animal is under general anesthesia, typically during surgery. In this experiment, animals were not anesthetized; therefore, a transmittance probe could not be used on the tongue. In contrast, a reflectance probe was used at 2 anatomical locations: 1) approximately 15 cm inside the rectum with placement against the ventral side of the sacral region of the vertebral column; and 2) orally against the nonpigmented upper gum and cheek of the restrained animal. According to Shapiro et al. (1989), the pulse oximeter predicts arterial oxygen saturation of hemoglobin using 2 wavelengths of light (near infrared and red light). The red light is absorbed by deoxygenated hemoglobin, whereas the near infrared light is absorbed by the oxygenated hemoglobin. To determine SpO_2, the transmittance probe measured the amounts of each light type that were reflected from the tissue. Saturation levels were differentiated between an artery and a vein because of the ability of the pulse oximeter to sense a pulse, which is unique to arteries.

Statistical Analyses. Statistical analyses of the data included calculation of Pearson correlation coefficients (Proc Corr, SAS Inst. Inc., Cary, NC) among all hemogram or SpO_2 values and PAP measurements. A parameter estimate, SE, and partial R^2 value were determined for each hemogram value using linear regression (Proc Reg of SAS) and the backwards model selection process with PAP score as the dependent variable. Prediction equations for PAP score were developed using multiple linear regression (Proc Reg of SAS), and all 10 hemogram values were used as independent variables in the stepwise model selection process in which an α value of 0.05 was required for a variable to enter and remain in the model.

Exp. 2

Experimental Design. In Exp. 2, 62 yearling Angus heifers and 22 yearling Angus bulls (born and raised at the same location as those evaluated in Exp. 1) were used to collect the following information: PAP score (mmHg) and 11 blood components: Na concentration, K concentration, PCV, HgB, pH, partial pressure of oxygen, saturation of oxygen, partial pressure of carbon dioxide, total carbon dioxide concentration, bicarbonate concentration, and base excess concentration. These blood components were predicted in a laboratory adjacent to the squeeze chute by using a portable clinical

analyzer (I-Stat portable clinical analyzer, Heska Corp.).

All PAP scores were collected as described in Exp. 1. Seventeen of the 84 animals evaluated in Exp. 2 had elevated (>45 mmHg) PAP scores. Immediately after the completion of the PAP test, blood was collected via jugular venipuncture, carotid arterial puncture, tail venipuncture, or tail arterial puncture using a 10-mL syringe and 20-ga needle. Collection of arterial blood was attempted first because it would provide a better indication of saturation of oxygen and partial pressure of oxygen than venous blood. In cases where an artery could not easily be located, venous blood was collected. Once whole blood was collected, approximately 1 mL was immediately placed into the well of a cartridge (EG6+ I-Stat cartridge, Heska Corp.), and the cartridge was inserted into the portable clinical analyzer for data collection. The results were typically available within 1 to 2 min. Some data points were lost because of difficulties with sample handling, including sample clotting before analysis by the clinical analyzer.

Statistical Analyses. In Exp. 2, all SAS procedures were the same as those described for Exp. 1. Pearson correlation coefficients were calculated among all portable clinical analyzer values and PAP measurements. A parameter estimate, SE, and partial R^2 value were determined for each portable clinical analyzer value using linear regression and the backwards model selection process with PAP score as the dependent variable. Prediction equations for PAP score were developed using multiple linear regression, and all 11 portable clinical analyzer values were used as independent variables in the stepwise model selection process.

RESULTS AND DISCUSSION

Exp. 1

Hemogram Values. In HAD-susceptible cattle, high PAP scores are caused by a significant change in the pulmonary vasculature as an animal attempts to compensate for hypoxic conditions. Additionally, cattle also appear to modify some characteristics of their blood, specifically red blood cells, to further compensate for hypoxia (Cueva, 1967). At high elevations, both cattle and humans have increased RBC numbers, circulating HgB concentrations (Cueva, 1967), and HgB affinity for oxygen (Ganong, 2001). For these reasons, the hemogram was included in this experiment to analyze the relationship between hemogram blood components and PAP score.

Of the 10 hemogram values (mean ± SD for each value reported in Table 1), PCV, HgB, and RDW were the only values correlated ($P < 0.10$) with PAP score (Table 2). When all 10 hemogram values were included in a regression model, the combined R^2 value was 0.375 relative to the PAP score (Table 3). When the model was reduced by the stepwise model selection process, only HgB and RDW were included ($P < 0.05$) in the model. The final reduced multiple regression model had an R^2 value of 0.305, which was the largest for any model that included only 2 variables (Table 4).

Hypoxic conditions present at high elevation cause erythropoiesis and hemoglobin synthesis, which can begin to occur in as little as 2 to 3 d after hypoxia is first experienced (Ganong, 2001). The increased hemoglobin concentration improves oxygen-carrying capacity, and a rightward shift occurs in the dissociation curve for

Table 1. Hemogram values for Exp. 1[1]

Item[2]	Mean ± SD
PCV, %	36.0 ± 2.55
HgB, g/dL	13.6 ± 0.88
RBC count, trillion/dL	9.1 ± 0.82
MCV, fL	39.7 ± 2.78
MCHC, g/dL	37.9 ± 0.72
RDW, %	23.8 ± 1.73
NC, million/L	12.0 ± 2.00
PLAT, billion/L	488.3 ± 97.16
MCH, pg	15.2 ± 1.10
MPV, fL	5.7 ± 1.11

[1]In Exp. 1, 10 hemogram values were determined from whole blood collected from 39 yearling Angus bulls immediately after a right heart catheterization procedure (to measure pulmonary arterial pressure) and catheter removal. Once collected, samples were placed on ice for 3 h before being transported to the laboratory, where a hemogram analysis was completed on each sample within 6 h from the time of collection.

[2]PCV = packed cell volume; HgB = hemoglobin concentration; RBC = red blood cell; MCV = mean cell volume; MCHC = mean cell hemoglobin concentration; RDW = red cell distribution width; NC = nucleated cells; PLAT = platelet count; MCH = mean corpuscular hemoglobin; MPV = mean platelet volume.

Table 2. Relationship of hemogram values with pulmonary arterial pressure (PAP) score (Exp. 1)[1]

	PAP score[2]	
Item[3]	r	*P*-value
PCV	0.31	0.06
HgB	0.33	0.04
RBC count	0.17	0.30
MCV	0.08	0.65
MCHC	–0.13	0.44
RDW	–0.36	0.03
NC	–0.12	0.45
PLAT	–0.11	0.50
MCH	0.05	0.77
MPV	–0.04	0.83

[1]In Exp. 1, 10 hemogram values were determined from whole blood collected from 39 yearling Angus bulls immediately after a right heart catheterization procedure (to measure pulmonary arterial pressure) and catheter removal. Once collected, samples were placed on ice for 3 h before being transported to the laboratory, where a hemogram analysis was completed on each sample within 6 h from the time of collection.

[2]Mean PAP (pulmonary arterial pressure; ±SD) in Exp. 1 was 45.5 ± 11.6 mmHg.

[3]PCV = packed cell volume; HgB = hemoglobin concentration; RBC = red blood cell; MCV = mean cell volume; MCHC = mean cell hemoglobin concentration; RDW = red cell distribution width; NC = nucleated cells; PLAT = platelet count; MCH = mean corpuscular hemoglobin; MPV = mean platelet volume.

Table 3. Full multiple regression model for pulmonary arterial pressure (PAP) score (Exp. 1)[1,2]

Item[3]	Coefficient	SE	R^2	*P*-value
PCV	3.54	5.34	0.010	0.48
HgB	10.32	15.07	0.178	0.01
RBC count	–20.13	17.54	0.012	0.44
MCV	–3.99	4.01	0.033	0.20
MCHC	0.53	4.10	0.000	0.90
RDW	–3.83	1.25	0.127	0.03
NC	–0.64	0.97	0.010	0.48
PLAT	0.00	0.00	0.001	0.82
MCH	–3.52	7.54	0.004	0.66
MPV	1.55	0.91	0.000	0.91
Total			0.375	

[1]In Exp. 1, 10 hemogram values were determined from whole blood collected from 39 yearling Angus bulls immediately after a right heart catheterization procedure (to measure PAP) and catheter removal. Once collected, samples were placed on ice for 3 h before being transported to the laboratory, where a hemogram analysis was completed on each sample within 6 h from the time of collection.

[2]Contains all hemogram values as independent variables in the model.

[3]PCV = packed cell volume; HgB = hemoglobin concentration; RBC = red blood cell; MCV = mean cell volume; MCHC = mean cell hemoglobin concentration; RDW = red cell distribution width; NC = nucleated cells; PLAT = platelet count; MCH = mean corpuscular hemoglobin; MPV = mean platelet volume.

oxygen and hemoglobin. In cattle, most of the research on response of oxygen transport mechanisms to hypoxia was published in the 1960s and 1970s with inconclusive results relative to biological significance. Cueva (1967) found differences in blood components between "susceptible" and "resistant" cattle at high elevation; differences were noted in hemoglobin dissociation curves PCV, MCV, and MCHC. Card (1977) also reported that cattle with increased PAP scores had increased values for PCV, HgB, red cell mass, and erythropoietin titers. The findings of the current experiment agree with previous results for PCV and HgB, but not for the MCV and MCHC differences reported by Cueva (1967).

No mention of a relationship between RDW and PAP score was found in the literature, most likely because of the recent development of the RDW prediction measurement. The RDW component of a hemogram is a red cell measurement that indicates the amount of variation in red blood cell sizes within a sample. In humans, increased RDW values can be evidence of anemia, iron deficiency, or red cell fragmentation (Lee et al., 1999; Beutler et al., 2001).

Table 4. Reduced multiple regression model for pulmonary arterial pressure (PAP) score (Exp. 1)[1,2]

Item[3]	Coefficient	SE	R^2	*P*-value
HgB	5.72	1.88	0.178	0.01
RDW	–3.06	0.96	0.127	0.03
Total			0.305	

[1]In Exp. 1, 10 hemogram values were determined from whole blood collected from 39 yearling Angus bulls immediately after a right heart catheterization procedure (to measure PAP) and catheter removal. Once collected, samples were placed on ice for 3 h before being transported to the laboratory, where a hemogram analysis was completed on each sample within 6 h from the time of collection.

[2]An α value of 0.05 was used as the criterion to include a variable in the reduced model.

[3]HgB = hemoglobin concentration; RDW = red cell distribution width.

The negative correlation in the current experiment between RDW and PAP score (r = –0.36; $P = 0.03$) is difficult to interpret. The RDW values in these bulls appeared to be high (mean = 23.8; range = 19.9 to 26.6) compared with the range (16 to 21) reported by the Colorado State University Veterinary Teaching Hospital Blood Analysis Laboratory (L. Vapp, unpublished data). Greater RDW values in these bulls may be indicative of iron deficiency or RBC fragmentation, which could result from both increased erythropoiesis and/or vasoconstriction of the pulmonary vessels. However, the possibility of an iron deficiency is unlikely based on previous mineral analyses of this cow herd (Stanton et al., 2000). This measurement needs to be examined further, possibly by comparing iron concentrations with PAP score or evaluating blood smears for RBC appearance. The current experiment did not address these issues.

Most notable in the hemogram results were the partial R^2 values of RDW and HgB compared with those of the other 8 variables. The R^2 value for the 2-variable model was inadequate to accurately predict PAP score because it was only able to explain 30.5% of the variability in PAP score. Comparatively, by adding the other 8 variables, the full model was only able to explain an additional 7% of the variability. Based on this, further research is needed to help identify additional or alternative blood components with comparable or larger partial R^2 values to enhance the ability to predict PAP score and ultimately HAD incidence.

Pulse Oximetry. Use of pulse oximetry to monitor SpO_2 during surgery in humans and animals has become very common. The easy, noninvasive, and accurate method of using a pulse oximeter to collect SpO_2 predictions was the primary reason to evaluate the relationship between SpO_2 and PAP score in cattle in the current experiment. Changes in HgB affinity in cattle reported by Cueva (1967) indicate that possible changes in SpO_2 may be occurring as well. In the current experiment, we evaluated the relationship between the SpO_2 prediction via pulse oximetry and PAP score.

Neither of the 2 SpO_2 values reported by the pulse oximeter were correlated with PAP score ($P > 0.10$) or with each other ($P > 0.10$; Table 5). In this study, pulse oximetry provided a prediction of SpO_2 within a short amount of time (1 to 2 min) at both anatomical locations using the reflectance probe; however, neither of these values was useful in predicting PAP score. Although not evaluated in the current experiment, it appears that the SpO_2 predictions collected did not accurately predict the true SpO_2 of these cattle, possibly because of 1) black skin pigmentation of Angus cattle and/or 2) motion artifact in the restrained and nonanesthetized

Table 5. Relationship of pulse oximeter arterial oxygen saturations with pulmonary arterial pressure (PAP) score and with each other (Exp. 1)

	PAP score[1]		POX-R[2]		POX-C[3]	
Item	r	*P*-value	r	*P*-value	r	*P*-value
POX-R	–0.06	0.73	—	—	–0.10	0.60
POX-C	0.10	0.61	–0.10	0.60	—	—

[1]Mean PAP (±SD) in Exp. 1 was 45.5 ± 11.60 mmHg.
[2]POX-R = pulse oximeter arterial oxygen saturation (SpO_2) prediction taken approximately 15 cm inside the rectum with placement against the ventral side of the sacral region of the vertebral column. Mean (±SD) SpO_2 for POX-R in Exp. 1 was 84.6 ± 9.35%.
[3]POX-C = pulse oximeter SpO_2 prediction taken against the upper gum and cheek. Mean (±SD) SpO_2 for POX-C in Exp. 1 was 89.0 ± 5.18%.

animals. In a typical production system, anesthetizing animals to use this technology would be both impractical and cost-prohibitive.

Anecdotal data observed by Heska Corp. (P. Perkins, personal communication) indicate that a pulse oximeter was inaccurate at predicting SpO_2 when the probe was applied to the tongue of a canine under anesthesia if the tongue had black pigmentation (e.g., the Chow-Chow breed of canine). Ongoing research and development of pulse oximetry will continue to focus on eliminating (or reducing) motion artifact sensitivity (P. Perkins, personal communication), which will be necessary if this technology is to be used on nonanesthetized livestock.

Although no relationship was observed between SpO_2 and PAP score, further research using pulse oximetry should be performed once limitations with motion artifact sensitivity are eliminated. Future experiments using nonblack-hided cattle, other anatomical locations, and additional probes (e.g., ear- and nose-clip transmittance probes) would be useful to determine whether this technology may be beneficial in the prediction of PAP score and ultimately HAD susceptibility.

Exp. 2

A portable clinical analyzer was evaluated for its ability to predict PAP score. This relatively new technology allows a veterinarian to observe blood parameter predictions chute-side rather than later in a laboratory. This technology involves use of a portable clinical analyzer instrument, which is about the size of a large television remote control device, and a large array of disposable cartridges to evaluate numerous blood parameters at reasonable cost and accuracy. This new technology was incorporated into Exp. 2 because it is meant to predict blood components that have been shown to be correlated with PAP score, such as PCV and HgB (Cueva, 1967).

None of the 11 blood components predicted by the portable clinical analyzer were correlated with PAP score ($P > 0.10$; Table 6). When these variables were combined in a multiple regression model, the 11 components explained only 12% of the variation in PAP score. This lack of a relationship with PAP score and the inability to help predict PAP score was probably due to a variety of factors.

Sixteen percent of the cartridges that were initially filled with fresh blood did not provide predicted values for any blood components. It appeared that this was due to immediate clotting of blood in the collection well of the cartridge, followed by a lack of capillary action, and an inability of the blood to flow across the electrodes, which are all vital for proper analysis. Clotting seemed to occur more rapidly when blood collection was difficult because of the inability to quickly find a blood vessel. This delay in collection coincided with some limited damage to the vessel caused during blood collection, possibly instigating increased activity of clotting factors that caused the sample to clot quickly in the cartridge. Ambient temperature was probably not a factor because the blood was added to the cartridge (immediately after

Table 6. Relationship of portable clinical analyzer blood values with pulmonary arterial pressure (PAP) score (Exp. 2)[1]

	PAP score[2]	
Item[3]	r	*P*-value
Na	–0.75	0.50
K	0.74	0.51
PCV	0.04	0.75
HgB	0.04	0.75
pH	0.12	0.28
pO_2	0.14	0.21
sO_2	0.16	0.16
pCO_2	–0.16	0.15
tCO_2	–0.12	0.27
HCO_3	–0.11	0.32
BE	–0.03	0.76

[1]In Exp. 2, 11 blood values were determined from whole blood collected from 84 yearling Angus cattle immediately after a right heart catheterization procedure (to measure PAP) and catheter removal. Once collected, 1 mL of sample was immediately placed into the well of a cartridge (EG6+ I-Stat cartridge, Heska Corp., Fort Collins, CO), and the cartridge was immediately inserted into a portable clinical analyzer (I-Stat portable clinical analyzer, Heska Corp.).
[2]Mean PAP (±SD) in Exp. 2 was 42.5 ± 8.13 mmHg.
[3]PCV = packed cell volume/hematocrit; HgB = hemoglobin concentration; pO_2 = partial pressure of oxygen; sO_2 = oxygen saturation; pCO_2 = partial pressure of carbon dioxide; tCO_2 = total carbon dioxide; BE = base excess.

Table 7. Portable clinical analyzer blood values for Exp. 2[1]

Item[2]	Mean ± SD
Na, mmol/L	138.8 ± 3.40
K, mmol/L	4.50 ± 0.735
PCV, %	34.6 ± 3.50
HgB, g/dL	11.9 ± 1.21
pH	7.50 ± 0.074
pO_2, mmHg	37.5 ± 11.37
sO_2, %	71.2 ± 15.61
pCO_2, mmHg	38.7 ± 7.26
tCO_2, mmol/L	31.2 ± 3.82
HCO_3, mmol/L	30.0 ± 3.70
BE, mmol/L	7.04 ± 3.901

[1]In Exp. 2, 11 blood values were determined from whole blood collected from 84 yearling Angus cattle immediately after a right heart catheterization procedure (to measure PAP) and catheter removal. Once collected, 1 mL of sample was immediately placed into the well of a cartridge (EG6+ I-Stat cartridge, Heska Corp., Fort Collins, CO), and the cartridge was immediately inserted into a portable clinical analyzer (I-Stat portable clinical analyzer, Heska Corp.).

[2]PCV = packed cell volume/hematocrit; HgB = hemoglobin concentration; pO_2 = partial pressure of oxygen; sO_2 = oxygen saturation; pCO_2 = partial pressure of carbon dioxide; tCO_2 = total carbon dioxide; BE = base excess.

it was collected) in a heated and enclosed laboratory (approximately 15°C) adjacent to the chute. A large amount of variation was also associated with several blood components predicted by the instrument (Table 7). This variation might have been associated with the difficulty in obtaining arterial blood consistently.

Although no relationship between blood parameters predicted by a portable clinical analyzer and PAP score were observed, based on the available literature, this was the first experiment that evaluated the ability of a portable clinical analyzer to predict PAP score. Further evaluation of this instrument, and several of its cartridges that predict parameters related to PAP score, would be beneficial.

The inherent susceptibility of beef cattle to HAD is an economic and animal health concern on high elevation ranches in the western United States. However, in the current experiment, only 3 blood parameters predicted by a hemogram were individually correlated with PAP. Use of 2 of these correlated variables in a prediction equation provided a moderate R^2 value in the prediction of PAP. Further research that incorporates additional blood components, technologies that can accurately and repeatedly predict blood parameters, other beef breeds, and larger sample sizes will be necessary to develop an accurate alternative to PAP testing. Development of an alternate test could lead to the genetic prediction of the disease in cattle, as well as the study of HAD in humans through the use of cattle as an experimental model.

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