Pulmonary Artery Pressure And Arterial Oxygen Saturation Of Indigenous And Crossbred Cattle Of Ethiopia Under Hypoxic Environment Of High Altitude -
*Z.Wuletaw**, M.Wurzinger*, T.Holt‡, T.Dessie§, J. Sölkner*

Introduction

Cattle in North Western Ethiopia are kept at altitudes of up to 4000 m and down to 550 m. Their phenotypic differentiation along levels of altitude is strong. The cattle in the region are different types, Zebu, Sanga and Zenga, a mixture Zebu x Sanga (Wuletaw (2004)). Crossbreds of local types with Holstein Friesian and Jersey are found at mid to high altitude (1,700 m – 2,700 m). High altitude environment is characterized by hypobaric hypoxia that causes reduction in the partial pressure of oxygen in inspired air. The resulting hypoxic condition presents a number of physiological challenges to high altitude animals (Schmidt-Nielsen (1997)). Among these is the high altitude or brisket disease of cattle known since 1889 (Tucker and Rhodes (2001)). The disease is characterized by right ventricular hypertrophy and edema of the chest and brisket, as a result of reduced blood oxygen saturation at high elevation (Holt and Callan (2007)) and is heritable in a range of 0.30-0.50 (Will et al. (1975); Enns et al. (1992); Shirley et al. (2008)). The incidence and severity of the disease increase with altitude (Rhodes 2005; Shirley et al. (2008)). Pulmonary artery pressure is an indicator of proneness to the disease. High values (> 50 mm Hg) indicate high risk and low values (< 35 mm Hg) indicate resistance to the disease (Rhodes (2005)). Animals suffer from physiological stress resulting from high altitude hypoxia that inhibits diffusion of oxygen from the air into the lungs. Consequently, less oxyhemoglobin is produced resulting in decreased transport of oxygen to the tissues (Schmidt-Nielsen (1997)). Pulse oximeter monitors blood oxygen saturation by calculating a value of percent arterial hemoglobin oxygen saturation (Tremper and Barker (1989)). The extent of proneness, epidemiology, and genetics of diseases like brisket is not, however, known in Ethiopia where a large proportion of the area is at altitudes above 2,700 m. The objective of the study is to learn about adaptive characteristics of indigenous cattle populations of Ethiopia and their crosses with European types towards hypoxic environment. Adaptation is measured via PAP test, and percent arterial hemoglobin oxygen saturation (**% SaO_2**) as predicted by pulse oximeter.

Materials and methods

Methods of data collection (high altitude pulmonary hypertension). To assess the proneness of animals to high altitude pulmonary hypertension, PAP test scores were taken from representative populations of indigenous and crossbreds of local types with Jersey and Holstein Friesian. The animals were restrained in a manually operated squeeze chute without use of anesthesia or sedatives. A rope halter controlled each animal's head during PAP testing. An experienced veterinarian from Colorado University took the records. 218 animals composed of three indigenous and three crossbred populations residing within the altitude range of 1,730 - 3,500 m had their pulmonary artery pressure measured via right heart and pulmonary artery catheterization (Holt and Callan (2007)).

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* BOKU - University of Natural Resources and Applied Life Sciences Vienna, Department of Sustainable Agricultural Systems, Division of Livestock Sciences, Gregor Mendel Str. 33, A-1180 Vienna, Austria
‡ Colorado State University, Department of Clinical Sciences, Fort Collins, CO 80523-1678 U.S.A.
§ ILRI - International Livestock Research Institute P.O.Box 5689, Addis Ababa, Ethiopia

Methods of data collection (arterial hemoglobin oxygen saturation). A pulse oximeter (**Eickemeyer oxyvet**) with a corresponding reflectance probe was used to collect % SaO_2 values. A transmittance probe was applied to the tail, a site with stable and intense signal and smallest bias (Coghe et al. (1999)), while the animal was standing. Pulse oximeter predicts arterial oxygen saturation of hemoglobin using two wavelengths of light, near infrared and red light (Shapiro et al. (1989)). The red light is absorbed by deoxygenated hemoglobin, whereas the near infrared light is absorbed by the oxygenated hemoglobin. 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. A similar approach was used by Coghe et al. (1999); Uystepruyst et al. (2000); and Ahola et al. (2006).

Data management and statistical analysis. PAP scores were analyzed using the Generalized Linear Model (GLM) of SAS (2002). Age and sex were not significant and excluded from the model so that the final model only included a single fixed effect (type of breed or cross). Due to lack of significance differences data collected from crosses of Jersey with indigenous and Friesian with indigenous genotypes at 2,700 m were merged and termed as 'high altitude crosses'. Similarly crosses of exotics with locals at 1,730 m are merged and represented as 'mid altitude crosses'. For oxygen saturation data nonparametric tests are employed.
Differences between means were tested for statistical significance by the nonparametric Kruskal-Wallis test with Bonferroni-Holm correction for multiple comparison posttest. A value of $P < 0.05$ was considered statistically significant for all tests.

Results and discussion

The results in Table 1 indicate that no sign of brisket disease is observed among the studied populations. All PAP scores (21- 47 mm Hg) fall within the range of low to moderate risks. Differences in means were not significant for any pair of populations. Some of the readings (values < 28 mm Hg) for the Semien cattle group measured at 3500 m are out of the range of readings of approximately 175,000 cattle that the veterinarian has taken in the Rocky Mountains in the course of 20 years. Crosses of the local cattle with Holstein Friesian and Jersey were not more prone to brisket disease than local cattle measured at the same altitudes. In a study comparing PAP readings in yak, cattle and their crosses (Anand et al. (1986)), the crosses had equally low PAP readings as the yaks. Yaks are known to be resistant to high altitude disease due to an adaptation of vascular system, indicated by thin-walled small pulmonary arteries.

Table 1: Studied populations, their respective location and corresponding PAP scores measured in millimeters of Mercury (mm Hg)

breed	altitude, m.	animals	PAP scores mean ± SD	PAP scores range
Overall	1730 - 3500	218	33.40 ± 3.94	21 – 47
Overall indigenous	1730 - 3500	126	33.08 ± 3.91	21 – 46
Fogera	1730	55	32.51 ±2.95	27 – 42
Wegera	2700	39	34.41 ± 3.44	28 – 42
Semien	3500	32	32.47 ± 5.36	21 – 46
Overall crosses	1730 - 2700	92	33.84 ± 3.96	28 – 47
Fogera x Friesian	1730	8	34.50 ± 2.66	31 – 39
Wegera x Friesian	2700	64	33.42 ± 4.15	28 – 47
Wegera x Jersey	2700	20	35.00 ± 3.49	30 – 41

A statistically significant decrease in the % SaO_2 to approximately 82 % was present in the high altitude animals. Arterial hemoglobin oxygen saturation tended to increase as the altitude decreases (Table 2). Differences for arterial hemoglobin oxygen saturation were significant ($p < 0.05$) between cattle populations residing at an elevation of 3,500 m and 550 m. Further, there is also significant difference ($p < 0.05$) between Simien and crossbreds of the mid altitude areas. A range of variation in % SaO_2 among healthy individuals (68 % – 99 %) was found which may indicate differences in physiological hypoxemia despite uniform ambient hypoxic stress. All mean values of % SaO_2 in the present study are lower than those of Hereford steers reported by Reeves et al. (1962), but greater than the finding of Bisgard et al. (1974) who reported 79 % saturation for calves at 3,400 m, but affected with brisket disease.

Will et al. (1962) reported mean SaO_2 value of 94 %, 87 % and 81 % of saturation from cattle categorized as control at 1,500 m, moderate hypertension at 3,000 m and severe hypertension groups at 3,000 m, respectively. An animal with saturation of 68 % developed congestive failure in that study.

Table 2: Arterial hemoglobin oxygen saturation (SaO_2) values as predicted by the Pulse oximeter

breeds	altitude, m	SaO_2[1], % mean ± SD	SaO_2 range, %
Overall indigenous	550-3500	85.00 ± 7.73	68 - 99
Simien	3500	82.45 ± 6.94[b]	70 - 99
Wegera	2700	84.17 ± 7.18[ab]	68 - 98
Metema	550	87.81 ± 8.26[a]	71 - 99
Overall crosses	1730-2700	86.22 ± 6.76	70 - 98
Mid altitude crosses	1730	87.28 ± 8.64[a]	70 - 98
High altitude crosses	2700	85.96 ± 6.30[a]	71 - 96
reference value		> 80%[2]	

[1] within a column, means without a common superscript differ ($P < 0.05$)
[2] Coghe et al. (1999)

Clinically relevant range reported for cattle is > 80 % SaO_2 (Coghe et al. (1999)). Coghe et al. (1999) also reported < 80 % of saturation from animals with clinical signs of undifferentiated bovine respiratory and all died. In our study we found values far below this range, down to 68 % saturation. Analyzed cumulative percentage on the distribution of percent hemoglobin oxygen saturation (Figure 1), showed that 9.62 % cattle living at 550 m, 25 % of 2700 m and 39.39 % of 3500 m have saturation values ≤ 80 %. We observed that all these animals are strong and healthy. Saturation range might go further down if overestimation of the Pulse Oximetry's percent arterial hemoglobin oxygen saturation Uystepruyst et al. (2000) is considered. In evaluating the accuracy of Pulse oximeter in neonatal calves, Uystepruyst et al (2000) reported a bias of +2.1 %. The bias tended to be greater for lower ranges of % SaO_2. Coghe et al (1999) also found a small bias between the measurements of % SaO_2 and arterial blood gas samples, with a tendency for Pulse oximeter to underestimate greater values and to overestimate lower values. The clinically relevant range reported for animals elsewhere, of > 80 % SaO_2 is therefore not applicable to cattle populations living at high altitude.

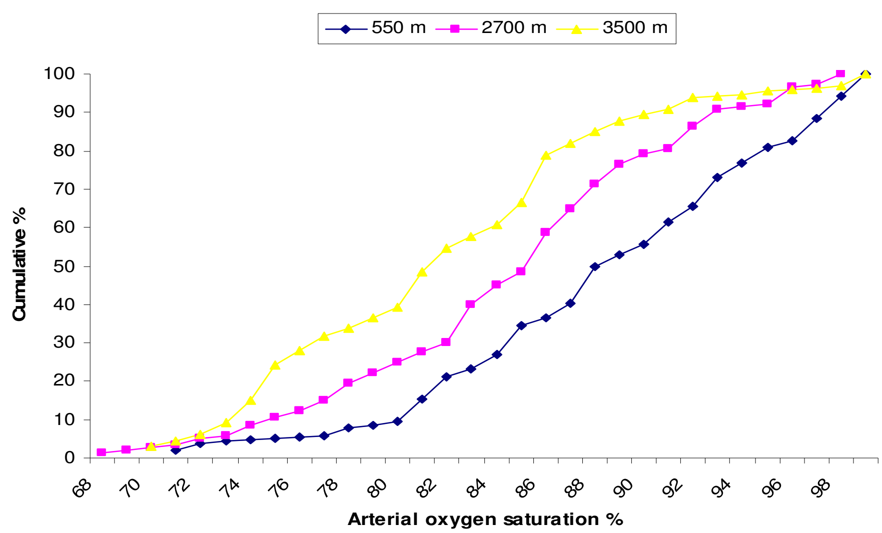

Figure 1: Cumulative frequency distribution of arterial oxygen saturation of Ethiopian cattle breeds residing at different altitudes. Oxygen saturation distribution of cattle residing at 550 m, 2700 m, and 3500 m, mainly contrasting throughout the distribution curve and overlapping only at a very low and very high percent saturation levels. Significant proportions of cattle found at 2700 m and above have saturation level ≤ 80 %.

In humans three successful pattern of adaptation models to high-altitude hypoxia (Andean, Tibetan and Simien Plateau of Ethiopia) have been reported (Beall et al. (2002)). People living on the Tibetan Plateau (4,000 m) exhibit little or no elevation of hemoglobin concentration compared to sea level population and show very low oxygen saturation. A similar pattern was found in our study. High-altitude indigenous cattle from the Simien Plateau of Ethiopia had hemoglobin concentrations (results not shown) that did not differ significantly from other cattle populations studied elsewhere (see for example Jain (1993): Silva et al. (1999) and have low arterial hemoglobin oxygen saturation.

Conclusion

These evidences show that Simien cattle probably have unique adaptations of oxygen uptake and delivery. We conclude that indigenous cattle of the Simien Plateau of Ethiopia are adapted genetically to high altitude by largely eliminating the hypoxic pulmonary vasoconstrictor response. The good adaptation is most likely due to natural selection.

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