Proceedings, The Range Beef Cow Symposium XXVI
November 18, 19 and 20 2019, Mitchell, Nebraska

Pulmonary Arterial Pressure EPD and Their Utility for Cow-Calf Producers.

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Introduction

High mountain disease (HMD) is a physiological condition that affects cattle residing in elevations greater than 5,000 feet. This disease is characterized by brisket edema stemming from right-sided heart failure, where ultimately, in the absence of corrective measures such as moving the animal to lower elevations, results in death. High mountain disease begins with pulmonary hypertension (PH). Typically, at high elevation, the hypoxic conditions resulting from lower atmospheric oxygen concentrations, cause the cardio-vascular system to work harder to increase blood oxygen concentrations. This increased workload results in increased pulmonary arterial pressure (PAP). As this PAP increases, the heart is required to work even harder to move the blood from an area of lower pressures to an area of higher pressure, resulting in excessive muscle contraction, stretching of muscle fibers and increased size of the right side of the heart. Eventually, when the heart chambers exceed their pumping capacity, the heart fails and the animal dies (Thomas et al., 2018)

Pulmonary arterial pressure is a trait, measured by veterinarians typically on replacement bulls and heifers that is used as an indicator of an animal's ability to tolerate high elevation conditions. Cattle with PAP measures ≤ 41 mmHg are considered to have a low risk of developing HMD, cattle with PAP measures ranging from 42 to 49 mmHg are considered to have a moderate risk of developing HMD and cattle with PAP measures ≥ 49 mmHg are considered high risk of developing HMD and are deemed unsuitable for life at higher elevations (Holt and Callan, 2007). In our research facility, consisting of 450 commercial Angus cows, at approximately 7,200 feet in elevation, 50% of replacement potential replacements are in the low-risk category, 40% are in the moderate-risk category and 10% are in the high-risk category (Thomas et al., 2018). Death loss due to HMD is extremely difficult to measure, due to the fact that producers who measure PAP in their potential replacements, attempt to mitigate these losses before they are realized. As a result of the lack of phenotypic data associated with HMD, PAP is only considered an indicator of an animal's ability to tolerate hypoxic conditions associated with high elevations.

Genetic Improvement of Pulmonary Arterial Pressure

Pulmonary arterial pressure is used as an indicator of an animal's ability to survive at elevation. A number of studies have reported the heritability of PAP and have found estimates for PAP to range from 0.25 to 0.46 with the actual estimates dependent on the breed makeup, age (weaning versus yearling) and elevation at which PAP is measured (Enns et al., 1992; Shirley et al., 2008; Zeng, 2013; Crawford et al., 2016; Culbertson et al., 2017; Pauling et al., 2018). In addition to the estimation of heritability, a significant effort has been undertaken to understand the genetic relationship between PAP and other economically relevant traits that receive selection pressure in a number of cow-calf producers' breeding objectives. Table 1, presented below, contains a number of these genetic correlations between PAP and traditional production traits.

Table 1. Genetic Correlations between Pulmonary Arterial Pressure and various production traits.

Trait	Shirley et al., (2008)[1]	Zeng, (2014)[2]	Crawford et al., (2016)[2]	Pauling, (2017)[2]
Birth Weight	0.49	0.22	0.15	-0.08
Weaning Weight	0.51	0.16	0.22	0.16
Milk	-0.05	0.10	-0.03	-0.15
Yearling Weight		0.11	0.12	0.02
Post-Weaning Gain		0.03	-0.10	-0.06
Back Fat				-0.03
Ribeye Area				0.24
Intramuscular Fat				-0.04

[1]Weaning Pulmonary Arterial Pressure
[2]Yearling Pulmonary Arterial Pressure

Given the results presented in the above table, there are few antagonistic relationships between PAP and traditionally recorded production traits. Additionally, given the magnitude of the heritability of PAP, a number of breeding programs have implemented PAP evaluations aimed at the selection of replacement animals suitable for producing progeny that are adaptable to high elevation production systems. The first PAP EPD produced for a breeding program occurred back in 1992. Colorado State University's John E. Rouse Beef Improvement Center began a progeny testing program for Angus sires involving the semen companies ABS, Select Sires and Genex in 2001. Genetic predictions for PAP began to proliferate in 2011. Most recently, the American Angus Association was the first to release a breed-wide PAP EPD for the purpose of identifying individuals with genetics favorable for high elevations (AAA, 2019). Given the recent availability of PAP EPD on widely used sires, some confusion has been evident with regard to how to use the available predictions. Cattle producers comfortable with using the PAP phenotype to rank individuals for high altitude adaptability have expressed some uncertainty with the use of the EPD for PAP.

Use of the Pulmonary Arterial Pressure EPD

Given the widespread release of a PAP EPD, questions have arisen regarding what should be used to identify individuals acceptable for use in high elevation production situations. To begin answering this question, we first need to clarify the differences between an EPD and a phenotype. During the Range Beef Cow Symposium held in 2017, Spangler and Weaber presented the argument for the value of the use of an EPD over the use of a phenotype for selection purposes. To understand their reasoning, we first need to understand the underlying components of a phenotype.

For any trait, a phenotype on an individual animal is composed of the genetics the individual possesses and the environment the animal experiences. Using terminology similar to that of Spangler and Weaber (2017), genetics can be divided into additive (A), dominance (D) and epistatic (I) effects. Environmental effects can be classified as both permanent (P) and temporary (T).

$$P = G_A + G_D + G_I + E_P + E_T$$

In terms of selection and subsequent genetic improvement, breeders should only be concerned with the additive genetic effect (G_A) of the individual because this is the only component in the above equation that is passed from generation to generation. Dominance and epistatic effects are genetic effects that manifest in the individual at conception. Environmental effects (E_P and E_T) are not passed from parent to progeny. An EPD is an estimate of the transmittable genetic effects (G_A) an individual carries. Therefore, for breeding purposes, animals should be selected on the basis of their transmittable genetic merit, of which EPD are estimates. Because of this, Spangler and Weaber (2017) recommended that selection decisions should be made on the basis of EPD, when present. They did suggest, however, if EPD are not available for a trait of interest, then use of a phenotype was an acceptable alternative.

While the authors of this work are in agreement with the information presented by Spangler and Weaber (2017), we recognize that PAP is a different type of trait. As discussed above, PAP is an indicator of an individual's susceptibility of HMD. With regard to the PAP phenotype, elevated measures can be caused by a number of factors that are both genetic and environmental, with a number of these environmental or non-genetic influences on PAP outlined by Thomas et al., (2018). These influences include factors such as whether or not the individual has experienced any sort of respiratory disease, the animal's overall level of fatness, the use of ionophores as well as other systematic effects such as sex, age and breed differences. All of these non-genetic effects can have a significant influence on an individual's PAP phenotype, and to reiterate, this phenotype is an indicator of the animal's ability to survive at elevation and subsequent susceptibility to HMD.

An animal's PAP phenotype is an indicator of their tolerance to elevation, therefore, when identifying animals that have the ability to survive at elevation, this phenotype must be considered. However, for breeding purposes, producers need to consider the PAP EPD of an individual, if available. When the goal of the producers is to identify sires that have the ability to produce progeny that are tolerant to elevation, the EPD should be considered because this is an estimate of the animal's transmittable genetic merit for high altitude adaptability. The EPD has removed all known environmental or systematic influences of PAP.

Conclusion

An estimates of an individual's transmittable genetic merit for PAP is captured in the form of a PAP EPD. An individual's PAP phenotype contains a number of non-genetic / non-transmittable influences on their ability to survive in high elevation production scenarios. When the goal of the producer is to identify sires that will produce progeny that have a greater chance of survival at elevation, the EPD should be considered because this is an estimate of the transmittable portion of their phenotype. If the goal of the producer is to identify individual animals that have the greatest chance of survival at elevation, the PAP phenotype of that animal needs to be considered because it captures not only their genetic merit for high altitude adaptability, but also captures the individual's non-genetic experiences that influence their ability for survival at elevation.

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