Veterinary and Animal Science 11 (2021) 100162

Contents lists available at ScienceDirect

Veterinary and Animal Science

journal homepage: www.elsevier.com/locate/vas

Impact of cria protection strategy on post-natal survival and growth of alpacas (*Vicugna pacos*)

Santiago Valenzuela [a], Ruth M. Benites [a], Juan E. Moscoso-Muñoz [b], Curtis R. Youngs [c], Oscar E. Gómez-Quispe [a,*]

[a] *Faculty of Veterinary Medicine and Zootechnics, Universidad Nacional Micaela Bastidas de Apurímac, Abancay, Perú*
[b] *Faculty of Agricultural Sciences, Universidad Nacional de San Antonio Abad del Cusco, Cusco, Perú*
[c] *Department of Animal Science, Iowa State University, Ames, Iowa 50011, United States*

ARTICLE INFO

Keywords:
Camelids
Corral
Shed
Neonates
Body vest

ABSTRACT

The objective of this study was to evaluate the impact of different management systems on the postnatal survival and growth of alpaca crias. The study was conducted during the alpaca calving season in the Peruvian Andes. Animals were fed on native pastures; during the day they went out to graze, but at night they were brought into a corral. A total of 150 alpaca singleton neonates were randomly assigned to one of three cria protection strategies immediately after consuming colostrum. The first group consisted of 50 crias who slept in an open-corral (OC) without shelter. The second group was comprised of 50 crias fitted with body vests (BV) who stayed overnight in an open-corral without shelter. The third group spent nights in a semi-open shed (SH). Cria survival was recorded daily, and body weight was recorded weekly. Survival to 12 weeks of age was higher ($P = 0.001$) for BV (100%) than for SH (76%) or OC (64%) which were not different from each other. Daily body weight gain (kg/day) during the first 12 weeks of life was higher ($P < 0.001$) for BV (0.17 ± 0.03) than for SH (0.14 ± 0.02) or OC (0.13 ± 0.04). There was no effect ($P < 0.979$) of cria sex on daily body weight gain. Results of this study revealed that fitting neonatal crias with a BV is a viable management strategy to enhance cria postnatal survival and daily body weight gain.

1. Introduction

The South American camelids (SAC) are distributed in high elevation areas of the Andean Mountains in Bolivia, Peru, Argentina and Chile (Quispe, Poma & Purroy, 2013). The SAC are composed of wild species (guanaco and vicuña) and domestic species (llama and alpaca). Among the domestic SAC, rearing of the alpaca (*Vicugna pacos*) represents the most important rural economic activity due mainly to production of fiber (Lupton, McColl & Stobart, 2006). From a social point of view, alpaca rearing is an important source of employment for people living in those regions (Montes, Quicaño, Quispe, Quispe & Alfonso, 2008) and constitutes a viable means to curb rural poverty (Quispe et al., 2013). From an environmental perspective, properly managed alpacas cause little to no damage to the ecosystem. Alpacas can live in challenging environmental conditions such as intense cold temperatures between −8 °C (Gómez-Quispe et al., 2019) to 18 °C (McGregor, Ramos & Quispe, 2012) and high altitudes ranging from 3500 m (Arias, Velapatiño, Hung & Cok, 2016) to 5350 m (Ormachea, Calsín & Olarte, 2015). Their typical diet is based on natural pastures of the families Poaceae, Cyperaceae, Asteraceae and Juncaceae, even during times of sparse rainfall (Montes et al., 2008). Alpacas can live in conditions under which other species (sheep and cattle) cannot be efficient (Lupton et al., 2006). The production of SAC provides enormous possibilities for the socioeconomic development of the impoverished regions where they are raised (FAO, 2005; Pinto, Martín & Cid, 2010).

The economic performance of most livestock operations hinges on reproductive efficiency. Unfortunately, in SAC in South America, pregnancy rate is usually low (<50%) at 30 days after mating (Alarcón, García & Bravo, 2012; Fernández-Baca, 1977). Given that SAC are classified as a monotocous species, survival of offspring from females who do successfully reproduce is crucial for the economic viability of SAC ranches. Cria survival depends greatly on conditions during the first few days after birth (Bustinza, Burfening & Blackwell, 1988) such as an adequate supply of colostrum (Garmendia, Palmer, DeMartini & McGuire, 1987; Weaver et al., 2000), proper nutritional management of the cria's dam (Hinojosa, Yzarra, Ruiz & Castrejón, 2019; Vaughan &

* Corresponding author.
E-mail address: oegomezq@hotmail.com (O.E. Gómez-Quispe).

https://doi.org/10.1016/j.vas.2020.100162
Received 10 December 2019; Received in revised form 14 December 2020; Accepted 15 December 2020
Available online 21 December 2020

Tibary, 2006), and protection against sudden changes in the environment (Barrington, Allen, Parroquia & Tibary, 2006).

High mortality of crias within the first 3–4 months of life is one of the major problems affecting profitability of alpaca raising (Martín, Pinto & Cid, 2010). Estimates of cria mortality vary widely (2.1% to > 50%), and mortality is influenced by the size of the production system and the type of management (Bravo, Garnica & Puma, 2009; FAO, 2005; Gallegos, 2013; Sharpe, Lord, Wittum & Anderson, 2009). Factors influencing cria mortality can be singular or a combination of causes, and they may include failure of passive antibody transfer, general immune system failures, highly infectious diseases, health and milking ability of the hembra, or rapid and substantial changes in climate (Ameghino & De Martini, 1991; FAO, 2005).

Cria mortality can be reduced with the application of prevention and control measures aimed at improving survival (Martín et al., 2010). Some alpaca breeders have adopted strategies designed to counteract the environmental challenge posed by low ambient temperatures (−8 °C at night). One such strategy is the use of sheds (adapted from cattle and sheep sheds) to provide physical protection of the animals. A second strategy is the use of an open corral where animals huddle together for sleeping at night. Lastly, some alpaca breeders are using body vests to protect crias that are born ill or born in adverse weather conditions (Whitehead, 2009). However, the manner in which each of these neonatal protection strategies affects the survival and live weight gain of alpaca crias has not yet been well documented.

Because the alpaca is an animal with substantially different physiology and behavior than other ruminant livestock species, management techniques designed for other species do not necessarily work in the alpaca (Fernández-Baca, 1977). Due to the paucity of studies on management strategies to provide protection for alpaca crias, this study was undertaken with the objective of comparing three different management strategies (semi-open shed, open corral, and cria body vest in an open corral) on alpaca cria survival and body weight gain to 12 weeks of age.

2. Materials and methods

2.1. Study location

The study was carried out in the community of Iscahuaca (district of Cotaruse, province of Aymaraes, department of Apurímac, Perú), located at a latitude of 14°24′42″, longitude of 73°12′12″ and altitude of 4193 m above sea level. During the study (January to April), the area had a cold climate with temperatures averaging 18 °C at noon and −3 °C at dawn, wind speed of 3–4 m/s, relative humidity of 75 to 82%, and average precipitation per year of 1088.5 mm (minimum of 513.4 mm; Cia. Minera Ares SAC, 2011). The main economic activity of residents in the region is agriculture. In the study area, approximately 19% of alpacas are privately owned and 81% are owned by communities.

2.2. Experimental animals and their nutritional management

This research was conducted in a privately managed herd during the alpaca birth season (January to April). During the day, alpacas grazed on native pastures consisting predominantly of *Festuca dolichopylla, Stipa ichu, Agrostis* spp., *Calamagrostis* spp. and to a lesser extent of *Hypochaeris glabra, Scirpus americanus, Muhlembergia* spp., and *Luzula spp.* Wide variability in biomass of these pastures (514 to 3033.6 kg DM/ha) has been found in ecosystems similar to that of this study (Aguirre & Oscanoa, 1985).

A total of 150 singleton neonates of the Huacaya breed was used for this study. Crias were randomly assigned to one of three treatments (described below) consisting of 50 individuals each (25 male and 25 female crias per treatment). Crias were allowed to ingest colostrum before they were individually identified and their birth weights were recorded (all within two to four hours after birth). This research was approved by the Ethics Committee of the National Universidad Nacional San Antonio Abad del Cusco (CBI-UNSACC-2020-005).

2.3. Experimental design

A completely randomized design was used for this experiment. Dependent variables included cria survival and cria body weight gain to 12 weeks of age. Independent variable included sex (male or female) and cria protection strategy (open corral, cria body vest housed in an open corral, or semi-open shed).

The protection of crias using body vests (designated as treatment **BV**) is illustrated in Fig. 1A. The body vest (BV) was made of waterproof nylon fabric for the outer shell and polar fleece fabric for the inner lining. The dimensions of the BV are shown in Fig. 1B; the BV was secured to the cria using strings on the front legs and under the torso. Crias and their dams grazed together during the day, and at night both were placed into a 600 m^2 open-corral constructed of stone (1.2 m high; Fig. 2). The BV remained in place until 12 weeks of age and was adjusted on a weekly basis as needed to accommodate cria growth.

The protection of crias using a semi-open shed (designated as treatment **SH**) is depicted in Fig. 3. Crias in this treatment group were pastured with their dams during the day, and at night they were housed together in a 560 m^2 drylot pen that included the shed. The shed was 3.5 m deep, 6 m wide, and had three side walls made of stone (wall height ranged from 1.8 to 2.5 m). The fourth "side" of the shed was a 1.2 m tall deployable wire fence; the roof was covered with galvanized calamine (Fig. 3).

The protection of crias using an open corral (designated as treatment **OC**) served as the "control group" for this study because this is the most common nighttime housing method used by alpaca ranchers in this region. After grazing during the day, crias and their dams spent the night in the 600 m^2 open corral enclosed by 1.2 m high stone walls (Fig. 2).

2.4. Data collection and analysis

Crias were individually identified shortly after birth, and birth weight was measured using a portable and hanging digital scale (Kambor®; Germany). Cria body weight was recorded at 7-day intervals through 12 weeks of age, and cria mortality was recorded daily. All measurements were made in the first three hours of the morning. Cria mortality was determined by necropsy and/or observation of premortem clinical signs. In this field study, the body weight of postpartum females was not recorded to avoid inducing stress on dams (thereby reducing milk production) and also to reduce the likelihood of crushing of crias (by dams attempting to avoid human contact). Hembras appeared healthy throughout the study, and no death of dams occurred.

Cria survival through 12 weeks of age was analyzed through a

Fig. 1. The body vest (BV) alpaca protection strategy. Panel A shows an alpaca cria wearing a BV. Panel B show the measurements of the BV worn by alpaca crias in treatment group BV.

Fig. 2. Structure of the open corral (built of stone) for nighttime housing of crias and their dams in the body vest (BV) and open corral (OC) treatment groups.

Fig. 3. Structure of the semi-open shed (built predominantly of stones) used for nighttime housing of alpaca crias and their dams in the SH treatment group.

bivariate analysis (survival and alpaca cria protection strategy: BV, SH, OC) using Fisher's exact test. Cria body weight gain per day was calculated prior to analysis as (Final weight - Initial weight) / Number of days of age at final weight). Cria body weight gain was analyzed using ANOVA with the main effects of cria protection method (BV, SH, OC), sex (male, female), and their 2-way interactions. No interaction between sex and cria protection method was found, so the final analysis included only the main effects. The comparison of means was performed using Tukey's test, and statistical significance was set at a P-value of less than 5%. All data processing and analysis was performed using the statistical software R (version 3.3.3).

3. Results

3.1. Survival of crias

Survival of crias to 12 weeks of age is shown in Table 1. Survival of BV crias (100%) was higher ($P < 0.001$) than survival of either SH crias (76%) or OC crias (64%) which were not different from one another ($P < 0.190$). There was no effect of cria sex on survival ($P < 0.999$). A total of 30 crias died during this study (overall mortality rate of 20%), and all deaths occurred within the first six weeks of cria life. The primary causes of cria mortality were diseases (enteritis, enterotoxemia, and pneumonia) and environmental factors (starvation and crushing; Table 1). Three SH crias died at night, and nine died during the day while grazing. Five OC crias died at night (2 near the wall of the corral and 3 near the middle of the corral), and 13 died during the day while on pasture. No medical interventions could be performed due to the vast area of grazing lands.

3.2. Body weight gain of crias

Daily body weight gain (kg/day) during the first 12 weeks of life (Fig. 4) was higher ($P < 0.001$) for BV crias (0.17 ± 0.03) than for either SH (0.14 ± 0.02) or OC crias (0.13 ± 0.04). There was no effect ($P < 0.979$) of cria sex on daily body weight gain through 12 weeks of age; body weight gain averaged 0.15 kg/d for both males and females.

4. Discussion

To our knowledge, this study comparing the impact of cria protection strategy on cria survival and cria growth rate is the first of its kind to be

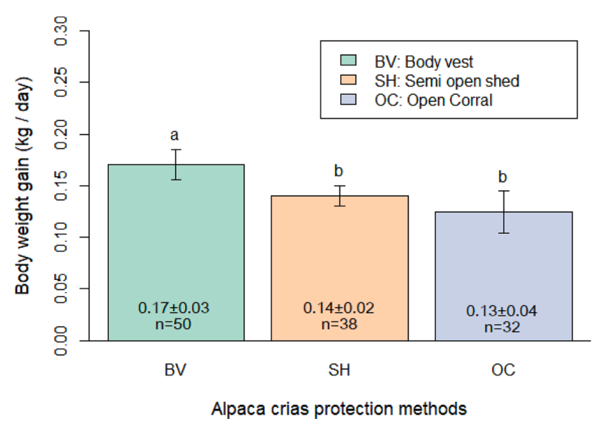

Fig. 4. Alpaca cria daily body weight gain (kg/day; model-based mean ± standard deviation) to 12 weeks of age under three different cria protection strategies (BV, SH and OC). Means with unlike superscripts (derived from Tukey's mean separation test) are different ($P<0.05$). Twelve SH crias and 18 OC crias did not survive to 12 weeks of age.

Table 1
Alpaca cria causes of mortality, survival rate to 12 weeks of age, and bivariate analysis between survival and alpaca cria protection strategy (BV, SH, OC).

Alpaca cria protection strategy[1]	Mortality causes[2]					Total Mortality n (%)	Total Survival n (%)	P-value for impact of cria protection strategy on alpaca cria survival[3]			Alpaca cria protection strategy[1]
	Enteritis	Enterotoxemia	Pneumonia	Starvation	Crushing			BV	SH	OC	
BV	0	0	0	0	0	0 (00%)	50 (100%)				BV
SH	4	1	4	2	1	12 (24%)	38 (76%)	0.001			SH
OC	3	3	6	4	2	18 (36%)	32 (64%)	0.001	0.275		OC

[1] Alpaca cria protection strategy: body vest (BV), semi open shed (SH) and open corral (OC).
[2] Diagnostic methods included necropsy and evaluation of pre-mortem clinical signs.
[3] Fisher's exact test.

performed in SAC in South America. The 20% cria mortality observed in this study was similar to the 22% mortality observed in one study (Davis, Keeble, Wright & Morgan, 1998) but was much lower than the 50% mortality reported in another (FAO, 2005). It was higher, however, than the 11.3% and 12% cria mortalities previously reported (Bravo et al., 2009 and Bustinza et al., 1998, respectively). Cria mortality may be due to failure of passive immunity transfer via colostrum (Garmendia et al., 1987; we attempted to circumvent this issue in the current study by ensuring colostrum intake by all crias), hypothermia due to heat loss (Pinares-Patiño, 2015; we attempted to directly prevent heat loss in BV crias), or low cria body weight (Motomura & Brent, 1998). Cria mortality has also been linked to diseases that occur in the first few months of cria life (D'Alterio, Knowles, Eknaes, Loevland & Foster, 2006; Rosadio, Maturrano, Pérez & Luna, 2012). Yet another factor that can lead to cria mortality is the lack of protection from harsh environmental conditions which can reduce the cria's body defenses (Martín et al., 2010). Inadequate design of alpaca shelters and/or an inadequate period of habituation for shelter use could certainly contribute to cria mortality.

The survival of crias in the present study was associated with cria protection strategy (i.e., BV, SH, or OC). Attention must be given to the environment, housing conditions, and proper neonatal care in order to reduce cria mortality (Davis et al., 1998), and disease prevention should also be addressed by ensuring immunoglobulin transfer which is associated with high neonatal survival (Ameghino & De Martini, 1991). One explanation for the extremely high rate of cria survival in our study (BV treatment) might be characteristics of the materials used in manufacture of the body vests. Characteristics such as conductivity, heat capacity, air trapping capacity, and thermal insulation of the polar fabric comprising the inner lining of the vest (Vargas, 2017) may have been crucial. Concomitantly, the impermeability to moisture and wind, the ability to prevent escape of cria body heat, and the breathability of nylon fabric comprising the outer shell of the body vest (Scarfone, 2014) may have also played a vital role. Together, these BV qualities may have favored homeostasis during the first week(s) of life, facilitated the retention of generated body heat (García, García, Muñoz-Muñoz & García, 1999), and controlled the activation of compensation mechanisms. These are all factors that give adult animals greater resistance to adverse climatic effects (Icuñaa, 2015; Pinares-Patiño, 2015).

The use of BV apparently avoided the loss of cria body heat during periods of intensely cold temperatures during the night, in spite of the fact that these animals slept in an open corral. Our results indicate that the use of BV to protect alpaca crias could be a valid strategy not only to decrease cria mortality but also to enhance weight gain compared with other alternatives. The BV cria protection strategy corresponds with the special care of alpaca crias suggested previously (Bustinza et al., 1988).

In the present study, there was no effect of cria sex on daily body weight gain. Our results agree with a previous study of alpacas raised under extensive conditions in both high- and low-elevation regions of Chile where no effect of cria sex on body weight of alpaca crias up to six months of age was observed (Raggi et al., 1997). This finding is unlike that which is commonly observed in other domestic livestock species.

In sheep, lower weight gains were found when using traditional sheds for housing compared with the use of heated sheds without grazing (Zhang et al., 2016). There was greater energy expenditure during the winter by sheep that were housed in an open corral versus those housed in a shed, as evidenced by an increase in heart rate (Raghavendra, Swain, Verma & Singh, 2005) which demands a greater amount of energy from the animal (Sleiman & Saab, 1995). When ambient temperatures were extremely cold, rectal temperature increased rapidly, followed by a gradual decline. Such changes indicate that the threshold of metabolic rate is reached quickly and that thermoregulatory mechanisms require substantial expenditure of energy (Raghavendra et al., 2005).

The low weight gains that we observed in alpaca crias housed in a SH (Fig. 4) could be explained to a great extent by the similar temperatures we recorded inside and outside of the shed (data not shown). The lack of warmer temperatures inside the shed seemingly resulted from an inadequate design of the sheds (e.g., shed wall height, shed having only three sides, type of roof; Fig. 3) for use in extremely cold temperatures. The lack of warmer temperatures inside the shed could also be due to the reluctance of animals to spend significant time inside the shed. We observed a large proportion of hembras and their crias permanently remaining outside of the SH (Fig. 3). Stress of animals inside sheds increases energy expenditure (Raghavendra et al., 2005), and this is likely to be detrimental to cria survival. It seems that it may be necessary to adapt/design sheds specifically for alpacas (and other SAC), taking into consideration their unique behaviors. Such thought is consistent with the sentiment that management strategies developed for other livestock species cannot be applied directly to camelids (Fernández-Baca, 1977).

Low body weight gains were also observed in crias housed in an OC. Similar results of lower animal productivity were reported for sheep and cattle housed during winter in an open corral because of the higher energy demand needed for maintenance (Arias, Mader & Escobar, 2008). When the ambient temperature decreases below animal body temperature, the animal loses heat to its surroundings and a greater production of metabolic heat is needed to maintain constant core body temperature (Tattersall et al., 2012). Alpacas with fine fiber (such as baby alpacas) that were exposed to high wind speeds exhibit greater heat loss (Moore, Blache & Maloney, 2011).

In the case of sheep, low ambient temperatures increase the secretion of thyroxine and triiodothyronine from the thyroid gland. The altered secretion pattern of these metabolic hormones modifies thermogenesis and increases gut motility and the rate of food passage, leading to a decrease in digestibility (Westra & Christopherson, 1976), an increase in energy expenditure at rest, and weight loss (Motomura & Brent, 1998). In general, extreme ambient temperatures produce lower weight gains (Young, 1981). Collectively, this means that the use of OC and existing designs of SH does not constitute the preferred method to mitigate cold stress, increase cria survival, and enhance cria weight gain in alpacas.

Greater variability of body weight gain was observed in alpaca crias housed in OC than in SH in the current study (standard deviation = 0.04: Fig. 4). This observation suggests the existence of individuals who seemingly were less affected than others by cold ambient temperatures. Based on government statistics, SAC may be more resistant to extreme changes in environment than other species (Icuñaa, 2015). If such speculation is accurate, it would be prudent to identify genes associated with cryo-tolerance and thermal stress and to consider genotype-environment interactions in the design of breeding programs (Das et al., 2016).

When comparing SH and OC in the present study, no association was seen between cria protection strategy and cria survival (Table 1). In sheep, lamb survival was higher when ewes were housed in a traditional shed with grazing than when ewes were housed in a heated shed without grazing (Zhang et al., 2016). These facts support the need to improve the environmental protection of the refuges (SH and OC) which would in turn improve survival of the alpaca crias.

Heat loss depends on the surface on which the air impinges (Kolkhorst, DiPasquale & Buono, 2002). For alpacas exposed to high wind speeds, a decrease in fiber diameter would correspond to an increase in the thermal conductivity of the fiber and skin (Moore et al., 2011), leading to the loss of body heat. Alpaca crias have thin skin and a low volume of subcutaneous fat, and their bodies are covered by short and thin fibers – resulting in a lower insulating capacity. This lower amount of insulation would easily allow for a reduction in animal body temperature when exposed to cold temperatures, high humidity and strong wind (Radostits, Gay, Hincheliff & Constable, 2007), as well as for greater sensitivity to cold stress (Pinares-Patiño, 2015). Consistent with the above, alpaca crias housed in an open corral showed a positive relationship between body weight and survival (Bravo et al., 2009).

5. Conclusion

There was higher cria survival (100%) and greater weight gain (0.17 kg/d) when crias wore a BV compared with crias housed during the night without a BV in a SH (0.14 kg/d, 76% survival) or in an OC (0.13 kg/d, 64% survival). Genetic sex of the cria had no effect on survival or weight gain to 12 weeks of age.

Declaration of Competing Interest

The authors declare that there was no conflict of interest.

Acknowledgement

This research was financially supported in part by the Universidad Nacional Micaela Bastidas de Apurímac located in Abancay, Perú (RR-178–2016).

References

Aguirre, L., & Oscanoa, L. (1985). *Mapeo de sitios, determinación de la condición y estimación de la soportabilidad ganadera en la estación experimental de camélidos sudamericanos la raya*. Perú: Instituto Interamericano de Cooperación para la Agricultura (IICA).
Alarcón, V., García, W., & Bravo, P. W. (2012). Artificial insemination of alpacas with semen collected by vaginal aspiration and by artificial vagina. *Rev Inv Vet Perú, 23* (1), 58–64. In Spanish.
Ameghino, E., & De Martini, J. (1991). *Alpacas offspring mortality. newsletter of the veterinary institute of tropical and height research (IVITA)* (pp. 71–80). Lima, Perú: Univ. San Marcos. In Spanish.
Arias, N., Velapatiño, B., Hung, A., & Cok, J. (2016). Cytokines expression in alpacas and llamas exposed to cold stress. *Small Ruminant Research, 141*, 135–140. doi.org/10.1016/j.smallrumres.2016.07.016.
Arias, R. A., Mader, T. L., & Escobar, P. C. (2008). Climate factors that affect the productive performance of beef and milk cattle. *Arch. Med. Vet., 40*, 7–22. https://doi.org/10.4067/S0301-732X2008000100002. In Spanish.
Barrington, G. M., Allen, A. J., Parroquia, S. M., & Tibary, A. (2006). Biosecurity and biocontainment in alpaca operations. *Small Rum Res, 61*, 217–225, 2006 https://doi.org/10.1016/j.smallrumres.2005.07.011.
Bravo, P. W., Garnica, J., & Puma, G. (2009). Cria alpaca body weight and perinatal survival in relation to age of the dam. *Animal reproduction science, 111*, 214–219. https://dx.doi.org/10.1016/j.anireprosci.2008.03.001.
Bustinza, A. V., Burfening, P. J., & Blackwell, R. L. (1988). Factors affecting survival in young alpacas (*Lama pacos*). *Journal of animal science, 66*(5), 1139–1143. https://doi.org/10.2527/jas1988.6651139x.
D'Alterio, G. L., Knowles, T. G., Eknaes, E. I., Loevland, I. E., & Foster, A. P. (2006). Postal survey of the population of South American camelids in the United Kingdom in 2000/01. *The Veterinary record, 158*, 86–90. https://doi.org/10.1136/vr.158.3.86.
Das, R., Sailo, L., Verma, N., Bharti, P., Saikia, J., Imtiwati, P., et al. (2016). Impact of heat stress on health and performance of dairy animals: A review. *Veterinary World, 9* (3), 260–268. https://doi.org/10.14202/vetworld.2016.260-268.
Davis, R., Keeble, E., Wright, A., & Morgan, K. L. (1998). South American camelids in the United Kingdom: Population statistics, mortality rates and causes of death. *The Veterinary record, 142*(7), 162–166. https://doi.org/10.1136/vr.142.7.162.
FAO [Food and Agriculture Organization of the United Nations]. (2005). *Current situation of south american camelids in perú. technical cooperation project in support of the breeding and exploitation of south american camelids in the andean region TCP/RLA/2914*. Roma, Italia: Publications management service of the FAO Information Directorate. In Spanish.
Fernández-Baca, S. (1977). Alpaca raising in the high Andes. *FAO [Food and agriculture organization of the united nations]. animal breeding: Selected articles from the world animal review*. Rome, Italy.
Gallegos, R. F. (2013). Production indexes of alpacas of the research and production center "La Raya". *Investig. Altoandin, 15*(2), 255–262. https://dialnet.unirioja.es/servlet/articulo?codigo=5893939. In Spanish.
García, A., García, F., Muñoz-Muñoz, R., & García, J. A. (1999). Viability and neonatal resuscitation in preterm infants of extremely low birth weight. *Anales espanoles de pediatria, 50*, 594–602.
Garmendia, A. E., Palmer, G. H., DeMartini, J. C., & McGuire, T. C. (1987). Failure of passive immunoglobulin transfer: A major determinant of mortality in newborn alpacas (*Lama pacos*). *American journal of veterinary research, 48*(10), 1472–1476.
Gómez-Quispe, O., Gutiérrez-Reynoso, G., Gallegos-Cardenas, A., Fumuso, F. G., Asparrin, M., Asparrin-Del Carpio, M., et al. (2019). Motility and recovery of alpaca (*Vicugna pacos*) spermatozoa after centrifugation in a density gradient solution. *IJVR, 2*(67), 96–104. https://doi.org/10.22099/IJVR.2019.5257, 20.
Hinojosa, R. A., Yzarra, A., Ruiz, J. A., & Castrejón, M. (2019). Structural characterization of the production system of alpacas (*Vicugna pacos*) in Huancavelica. *Peru. Arch. Zootec, 68*(261), 100–108, 2019. In Spanish.
Icuñaa, S. (2015). Camelids in the Andes of Bolivia and climate change. *Rev. Investig. Altoandin, 17*(3), 469–472. https://doi.org/10.18271/ria.2015.167. In Spanish.
Kolkhorst, F. W., DiPasquale, D. M., & Buono, M. J. (2002). Effect of tapwater iontophoresis on sweat gland recruitment, skin temperature and skin blood flow. *Dermatol. Sci., 28*, 97–101. https://doi.org/10.1016/S0923-1811(01)00142-6.
Lupton, C. J., McColl, A., & Stobart, R. H. (2006). Fiber characteristics of the Huacaya alpaca. *Small ruminant research : the journal of the International Goat Association, 64* (3), 211–224. https://doi.org/10.1016/j.smallrumres.2005.04.023.
Martín, C., Pinto, C. E., & Cid, M. D. (2010). South American camelids: Health status of their young. *Revista Complutense de Ciencias Veterinarias, 4*(1), 37–50. In Spanish.
McGregor, B. A., Ramos, H. E., & Quispe, E. C. (2012). Variation of fibre characteristics among sampling sites for Huacaya alpaca fleeces from the High Andes. *Small Ruminant Research, 102*(2012), 191–196. https://doi.org/10.1016/j.smallrumres.2011.07.016.
Montes, M., Quicaño, I., Quispe, R., Quispe, E., & Alfonso, L. (2008). Quality characteristics of Huacaya alpaca fibre produced in the Peruvian Andean plateau region of Huancavelica. *Spanish J. of Agric. Res., 6*(1), 33–38.
Moore, K. E., Blache, D., & Maloney, S. K. (2011). Fibre diameter and insulation in alpacas: The biophysical implications. *Small ruminant research : the journal of the International Goat Association, 96*(2), 165–172. https://doi.org/10.1016/j.smallrumres.2011.01.012.
Motomura, K., & Brent, G. A. (1998). Mechanisms of thyroid hormone action. Implications for the clinical manifestation of thyrotoxicosis. *Endocrinol. Metab. Clin. N. Amer., 27*, 1–23. https://doi.org/10.1016/S0889-8529(05)70294-2.
Ormachea, E., Calsín, B., & Olarte, U. (2015). Textile fiber characteristics huacaya alpacas of Corani district Carabaya. *Puno. Rev. Investig. Andina, 17*(2), 215–220. doi.org/10.18271/ria.2015.115.
Pinares-Patiño, C. (2015). *Role of south american camelids in mitigating and adapting to climate change. P798–809*. Puno – Perú: VII World Congress of South American Camelids. In Spanish.
Pinto, Ch. E., Martín, C., & Cid, M. D. (2010). South American camelids: Classification, origin and characteristics. *Revista Complutense de Ciencias Veterinarias, 4*(1), 23–36. In Spanish.
Quispe, E., Poma, A., & Purroy, A. (2013). Productive and textile characteristics of the Huacaya alpacas fiber: A review of Huacaya alpacas fiber traits. *Revista Complutense de Ciencias Veterinarias, 7*(1), 1–29. https://doi.org/10.5209/rev_RCCV.2013.v7.n1.41413. In Spanish.
Radostits, O. M., Gay, C. C., Hincheliff, K. W., & Constable, P. D. (2007). In O. M. Radostits, C. C. Gay, K. W. Hinchcliff, & P. D. Constable (Eds.) (10th Ed., p. 2156). Philadelphia, PA, USA: Elsevier Saunders.
Raggi, L. A., Macniven, V., Rojas, R., Castellaro, G., Zolezzi, M., Latorre, E., et al. (1997). Characterization of alpacas (*Lama pacos* [sic]) body weight gain from birth to six months of age in four regions of Chile. *Agro. Sur., 25*(2), 2019–2226. In Spanish.
Raghavendra, B., Swain, N., Verma, D. L., & Singh, N. P. (2005). Effect of housing on physiological responses and energy expenditure of sheep in a semi-arid region of India. Asian-Aust. *Journal of animal science, 18*(8), 1188–1193. https://doi.org/10.5713/ajas.2005.1188.
Rosadio, A., Maturrano, L., Pérez, D., & Luna, L. (2012). Neonatal enteric complex in Andean alpacas. *Rev Inv Vet Perú, 23*(3), 261–271. https://doi.org/10.15381/rivep.v23i3.908.
Scarfone, C. (2014). *Smart urban coat: Textile technology applied to clothing design*. Buenos Aires, Argentina: Faculty of Design and Communication, Universidad de Palermo. Bachelor thesisIn Spanish.
Sharpe, M. S., Lord, L. K., Wittum, T. E., & Anderson, D. E. (2009). Pre-weaning morbidity and mortality of llamas and alpacas. *Australian veterinary journal, 87*(1), 56–60. https://doi.org/10.1111/j.1751-0813.2008.00377.x.
Sleiman, F. T., & Abi Saab, S. (1995). Influence of environment on respiration, heart rate and body temperature of filial crosses compared to local Awassi sheep. *Small ruminant research : the journal of the International Goat Association, 16*, 49–53. https://doi.org/10.1016/0921-4488(95)98451-Y.
Tattersall, G. J., Sinclair, B. J., Withers, P. C., Fields, P. A., Seebacher, F., & Cooper, C. E. (2012). Coping with thermal challenges: Physiological adaptations to environmental temperatures. *Compr. Physiol, 2*(3), 2151–2202. https://doi.org/10.1002/cphy.c110055.
Vargas, C. D. (2017). *Polar garments for climbers using waste from the sports textile industry as filler. bachelor thesis. school of industrial design*. Pontificia Universidad Católica del Ecuador. Ecuador. In Spanish.
Vaughan, J. L., & Tibary, A. (2006). Reproduction in female South American camelids: A review and clinical observations. *Small Rumin Res, 61*, 259–281, 2006 doi.org/10.1016/j.smallrumres.2005.07.015.
Weaver, D. M., Tyler, J. W., Scott, M. A., Wallace, L. M., Marion, R. S., & Holle, J. M. (2000). Passive transfer of colostral immunoglobulin G in neonatal llamas and alpacas. *Am J Vet Res, 61*(7), 738–741. https://doi.org/10.2460/ajvr.2000.61.738.
Westra, R., & Christopherson, R. J. (1976). Effects of cold on digestibility, retention time of digesta, reticulum motility and thyroid hormones in sheep. Can. *Journal of animal science, 56*, 699–708. https://doi.org/10.4141/cjas76-083.
Whitehead, C. E. (2009). Management of neonatal llamas and alpacas. *Vet. Clin. North Amer. Food Anim. Pract., 25*(2), 353–366. https://doi.org/10.1016/j.cvfa.2009.03.006.
Young, B. A. (1981). Cold stress as it affects animal production. *Journal of animal science, 52*, 154–163. https://doi.org/10.2527/jas1981.521154x.
Zhang, X. Q., Kemp, D., Hou, X. Y., Langford, C. M., Wang, K., & Yan, W. H. (2016). Effects of shed modifications on ewe reproductive performance and lamb growth rate in Inner Mongolia. *The Rangeland Journal, 38*, 479–487. https://doi.org/10.1071/RJ15127.